CRWR Online Report 06-05

Introduction to Arc-Hydro: ACEH Basin Pilot Study

by

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May 2006

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Preface

This work benefits from the tremendous efforts of colleagues and former students at The University of Texas at Austin, including: David R. Maidment, Sergio Martinez, Carlos Patiño-Gomez, Oscar Robayo, Victoria Samuels, Kristina Schneider, Rebecca Teasley, and Tim Whiteaker. Any errors are those of the author.

1. Geodatabases

1.1 Introduction

The development of a watershed-scale database is fundamental to modern concepts of effective water resources management, especially at the national scale. Integral databases that include knowledge and information available about a country's river basins are often fragmented, disjointed, incomplete, and sometimes inaccurate. Integrated management of river basins requires the development of models that are used for many purposes, e.g., to assess risks and possible mitigation of droughts and floods, manage water rights, assess water quality, and simply to understand the hydrology of the basin. For this purpose databases are needed from which models can access the various data needed to describe the systems being modeled. In other words, a database from which models read input data and to which they write output data. In order for this concept to work, however, it must have a standard design. The ArcHydro data model was developed to facilitate organization of water resources data according to the "basin" principle and to allow access to hydrologic information by models (Maidment, 2002).

A Geographic Information System (GIS) is general-purpose technology for handling geographic data in digital form. Its abilities include: preprocessing data into a form suitable for analysis, supporting spatial analysis and modeling directly, and post processing results (Goodchild, 1993). GIS can offer spatial representation of water resource systems, bring spatial dimensions into water resource databases, and present an integrated view of the basin. This is accomplished by combining various social, economic and environmental factors related to spatial entities of a water resources problem and making them available for use in a decision-making process (Csillag, 1996).

The recent developments related to geodatabase construction for river basin planning have included the extension of the ArcHydro data model to include preprocessing of water resources model parameters. The WRAPHydro data model was derived from the ArcHydro model for the Water Rights Analysis Package (WRAP) implemented in Texas for the Texas Commission on Environmental Quality (TCEQ). This data model is structured to suit the needs of the WRAP parameter processing. WRAP is a hydrological simulation model to evaluate existing water right permits, permit approvals for new water rights, and overall water management in Texas under a priority based water allocation system (Wurbs and Dunn, 1996). More recently, WRAPHydro (Gopalan and Maidment, 2003) has been used to create ArcHydro geodatabases for large water resources problems, including the Rio Grande basin (Patiño-Gomez and McKinney, 2005) and the nation of Ethiopia (Asamenaw and McKinney, 2005).

1.2 Obtaining Software

The work described in this report requires three special software packages, one commercial (ArcGIS) and two public domain (ArcHydro Tools and WRAPHydro Tools):

1. **ArcGIS** from ESRI with an ArcInfo license and the Spatial Analyst extension active.

2. **ArcHydro Tools**, developed at The University of Texas at Austin, Center for Research in Water Resources (CRWR), and maintained and freely distributed by ESRI:

ftp site: ftp.esri.com
User: RiverHydraulics
Password: river.1114

3. **WRAPHydro Tools**, developed at The University of Texas at Austin, CRWR, and maintained and freely distributed by CRWR:

http://www.ce.utexas.edu/prof/maidment/grad/whiteaker/hydrotools.html

1.3 Overview of the data

1.3.1 Introduction

In this section you will build

- a **basemap** of geographic and streamflow data for a watershed using the Aceh Basin in Sumatra, Indonesia as an example. The basemap comprises basin watershed boundaries and streams from shapefiles.
- a **geodatabase** to hold all these data layers and to create relationships inside the geodatabase.
- a point **feature class** of stream gage sites by inputting latitude and longitude values for the gages in an Excel table that is added to ArcMap and the geodatabase

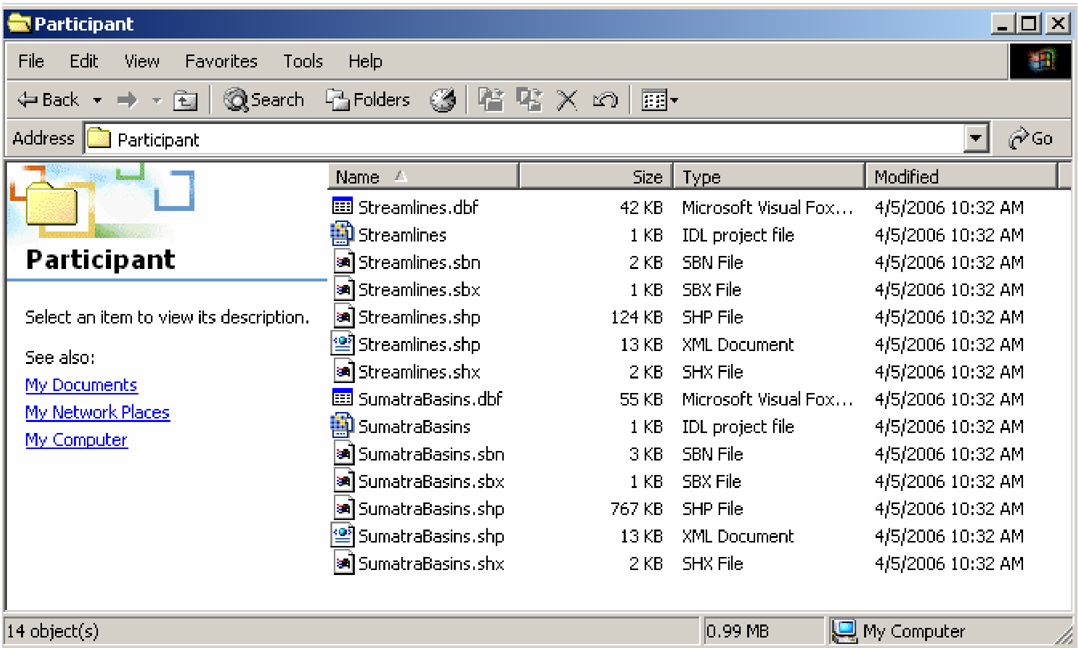
Log on to the computer of your choice and make a directory in your workspace for this exercise. The needed files are located in the course directory:

\ArcHydro_Aceh\Exercises_Data\Participant

The files include shapefiles of:

- **Basin polygons** – Needed to identify the basin of interest plus a surrounding buffer zone. Basin polygon and stream shapefiles are often available from government information systems and may be found on the Hydro 1K website for Australasia for our study area (http://edc.usgs.gov/products/elevation/gtopo30/hydro/australasia.htmlf).

- **Streams** – Needed to recondition a Digital Elevation Model (DEM) of the study area and serve as the main river network. These lines sometimes are not available or are not of sufficient quality. Our streamlines are not sufficient to recondition the DEM and will be estimated directly from the DEM in Section 4.



The files:

- SumatraBasins.*
- Streamlines.*

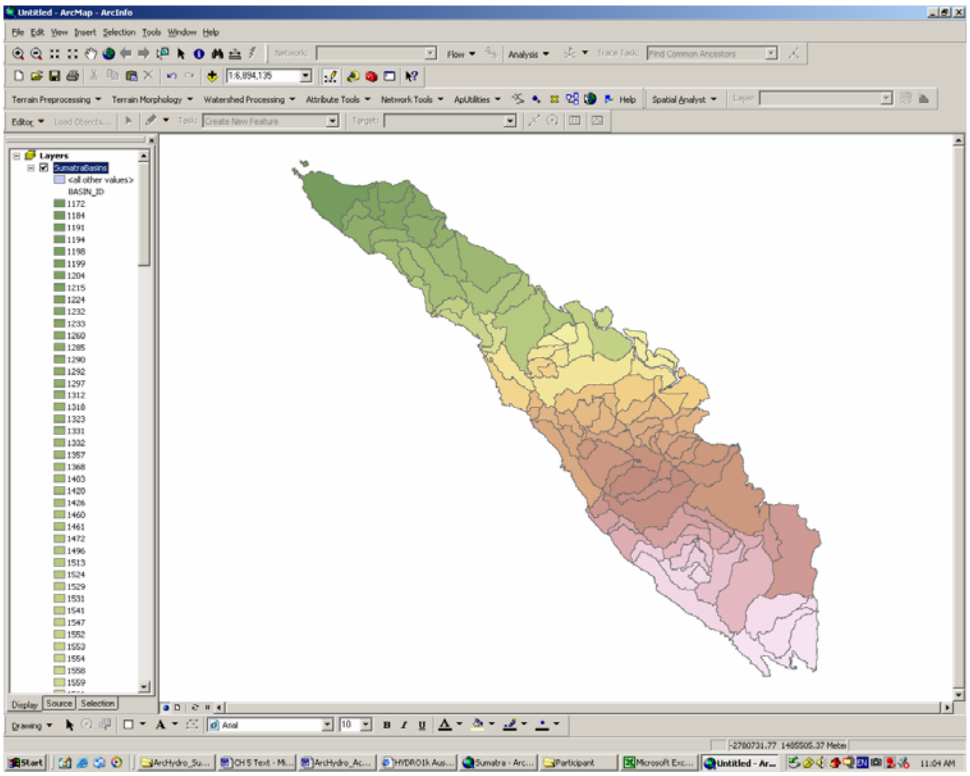
define the **SumatraBasins** (basin boundary polygons) and the **Streamlines** (river lines) shapefiles.

1.3.2 Stream and Watershed Data

The geospatial data files defining the Sumatra basins are located in the shapefile **SumatraBasins**. The rivers for Sumatra are contained in the shapefile **Streamlines**.

Note that each shapefile is comprised of various files and, therefore, it is easy to make errors when copying these files to another location. It is recommended that you use **ArcCatalog** to copy geospatial data files from one place to another in your workspace, rather than using the **Copy** function in Windows Explorer.

- Open **ArcMap** and add the shapefile **SumatraBasins** to the map.

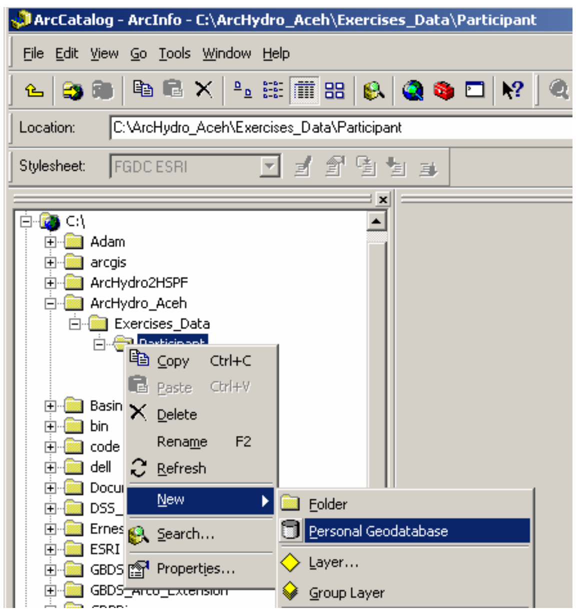


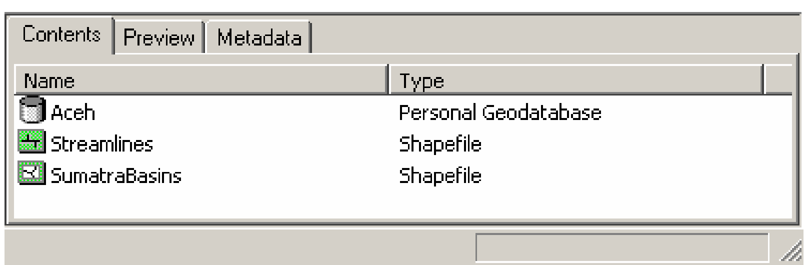
Recolor the themes if you wish. Move the cursor to the lower left corner of the display, and you'll see the coordinates changing at the bottom of the map display. The coordinates shown here are approximately (**-3,605,214 m**; **932,810 m**). If you move the cursor to the upper right corner of the rectangle, you will find approximately (**-1,713,647 m**; **2,289,923 m**). You now have the **reference coordinates** for Sumatra.

1.3.3 Creating a Geodatabase

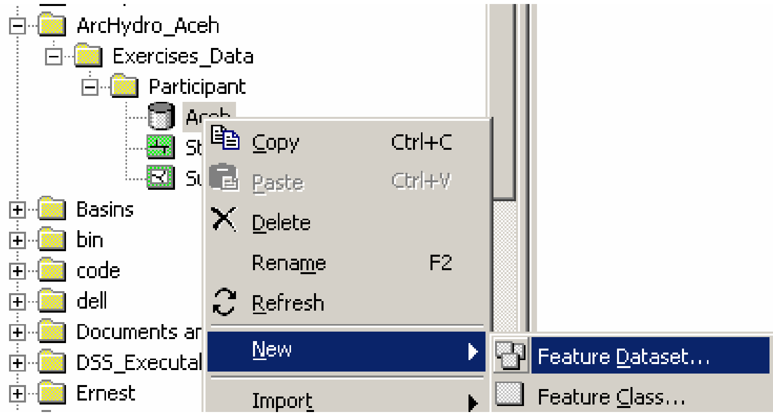
ArcGIS uses an object-oriented data model called the geodatabase. This data model gives the features in your GIS datasets custom behaviors and the possibility to create relationships between features. In general, a geodatabase model provides a standardized framework into which various types of data can be loaded. Once created, the geodatabase is a **Microsoft Access file** called an **ArcGIS personal geodatabase**.

- Close **ArcMap** and open **ArcCatalog**.
- Right click on the **Participant** folder and select **New / Personal Geodatabase**. Name the new geodatabase **Aceh**.

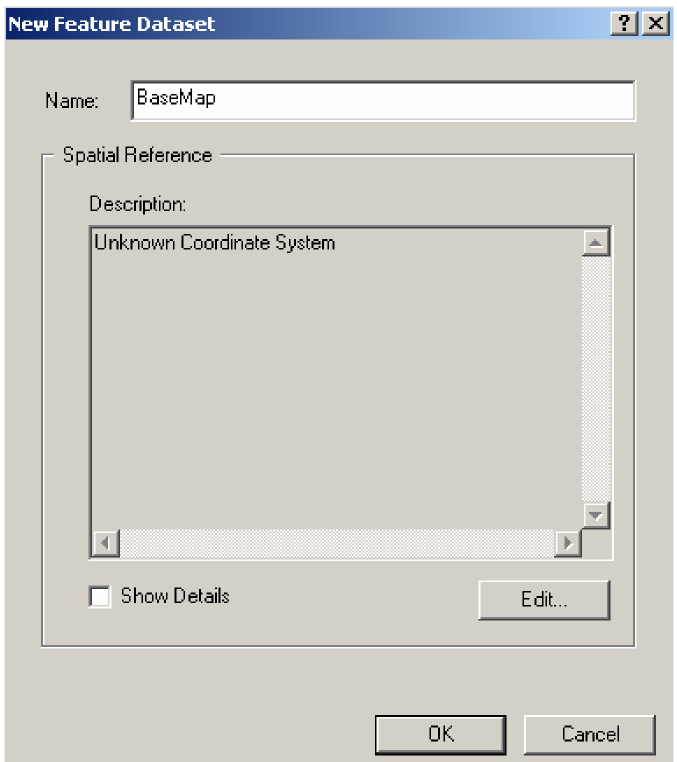




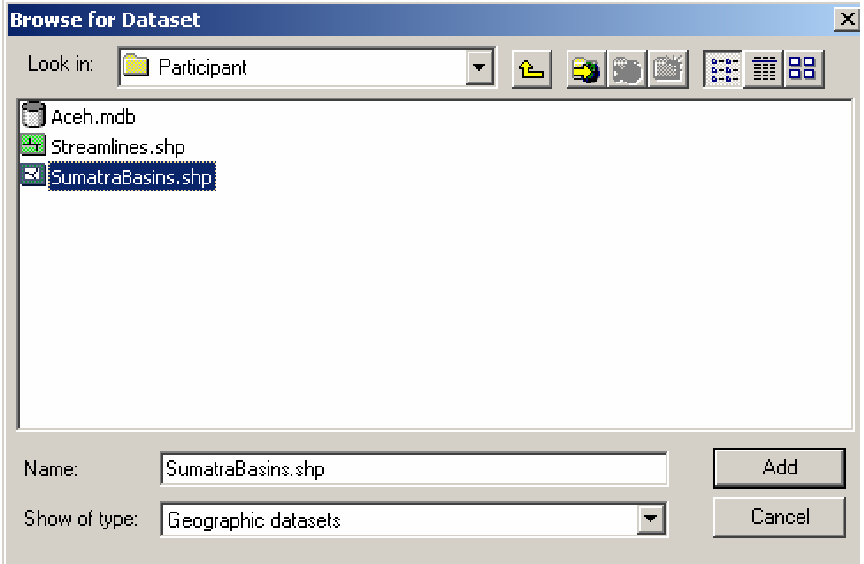
- Right click on the **Aceh** geodatabase and select **New / Feature Dataset**.



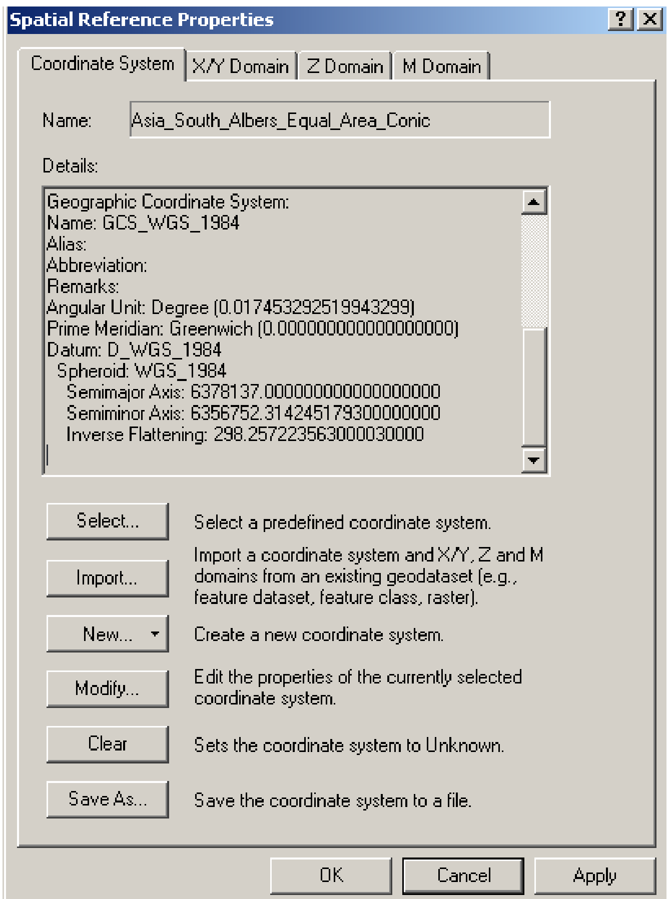
- Name the new feature dataset **BaseMap** and select **Edit** to set the projection and map extent.



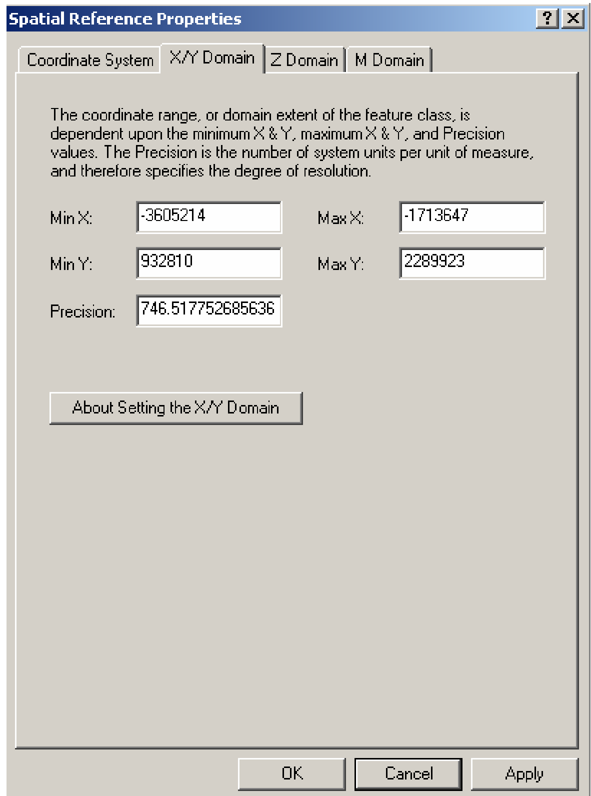
We will import the coordinate system from the **SumatraBasins** shapefile. Select **Import** from the choices in the menu display and navigate to the **SumatraBasins** shapefile.



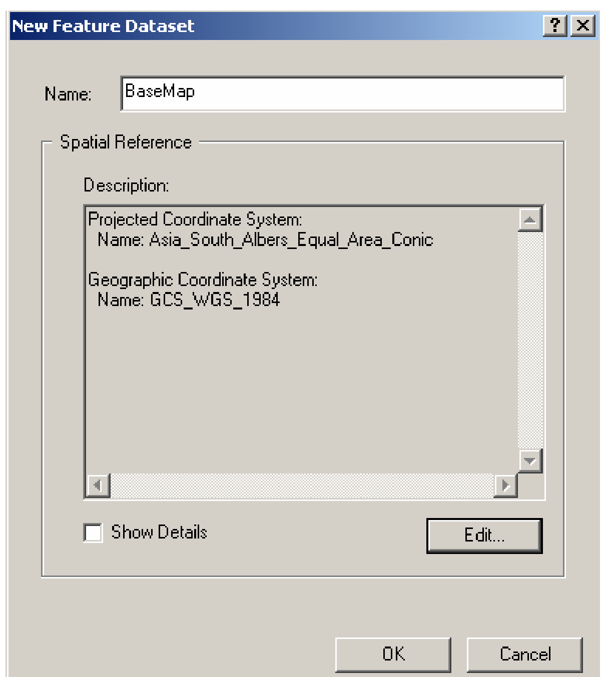
The coordinate system is now specified:



- Click the **X/Y Domain** tab and enter the coordinates that we found earlier in ArcMap: **MinX** = **-3605214**, **MaxX** = **-1713647, MinY = 932810**, **MaxY** = **2289923.**



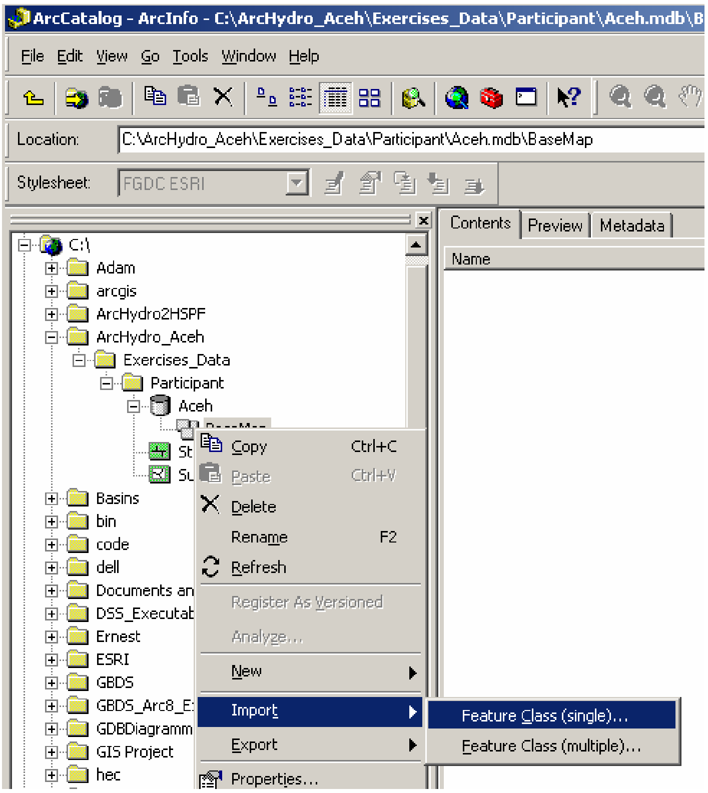
- Click **Apply** and **OK** to finish setting the Spatial Reference Frame of the Feature Dataset.



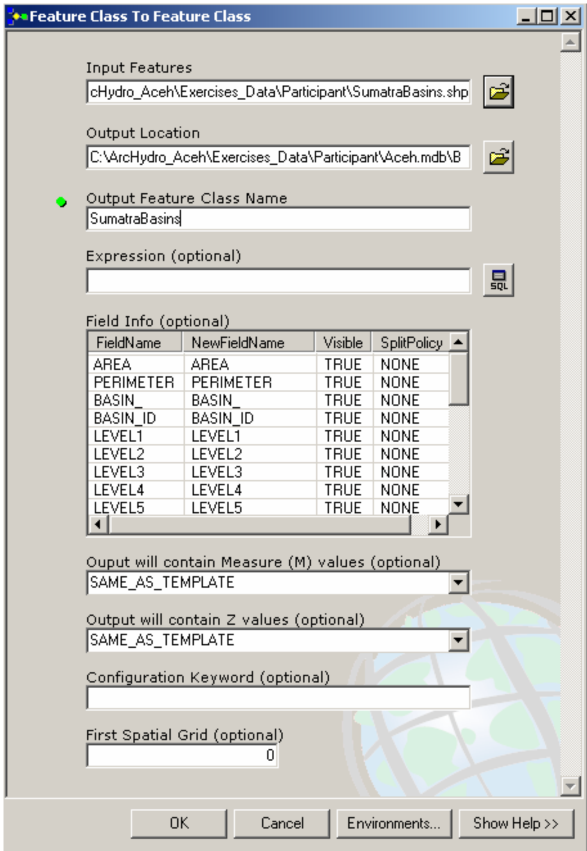
1.3.4 Importing Data into a Geodatabase

We will now import both of the shapefiles into the Aceh geodatabase. We will first import the **SumatraBasins** shapefile since this file has the largest extent and the geodatabase will adopt the spatial reference of the first imported feature class.

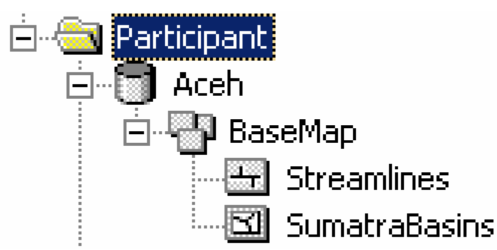
- Right-click on the **BaseMap** feature dataset and click **Import / Feature Class (single)**.



- In the *Input Features* field browse for the shapefile **SumatraBasins** and select it.
- In the *Output Feature Class Name* field type the name **SumatraBasins**.
- Do not enter any information in any of the other fields. Click **OK**.



- Repeat the same process to input the **Streamlines** shapefile and give it the name **Streamlines** in the *Output Feature Class Name* field.
- Congratulations! You have finished creating the **BaseMap** feature dataset with its two new feature classes (**Streamlines** and **SumatraBasins**).
- The final product should look as follows in **ArcCatalog**.

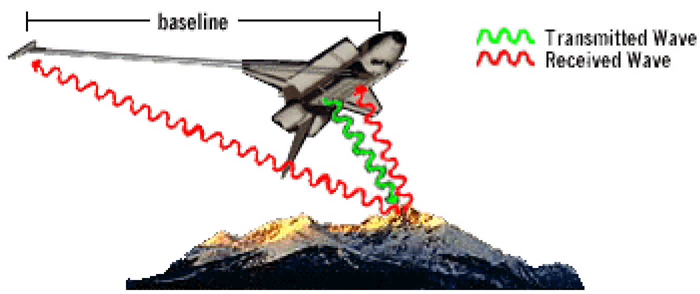


2. Preparing DEM Datasets

2.1 Global DEM Datasets

2.1.1 Downloading SRTM Data

The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. The data are published in 1 arc second (30 m resolution) grids for the US and 3 arc second (90 m resolution) grids for the rest of the globe from 56° S - 60 ° N latitude.



Radar signals being transmitted and recieved in the SRTM mission (image not to scale).

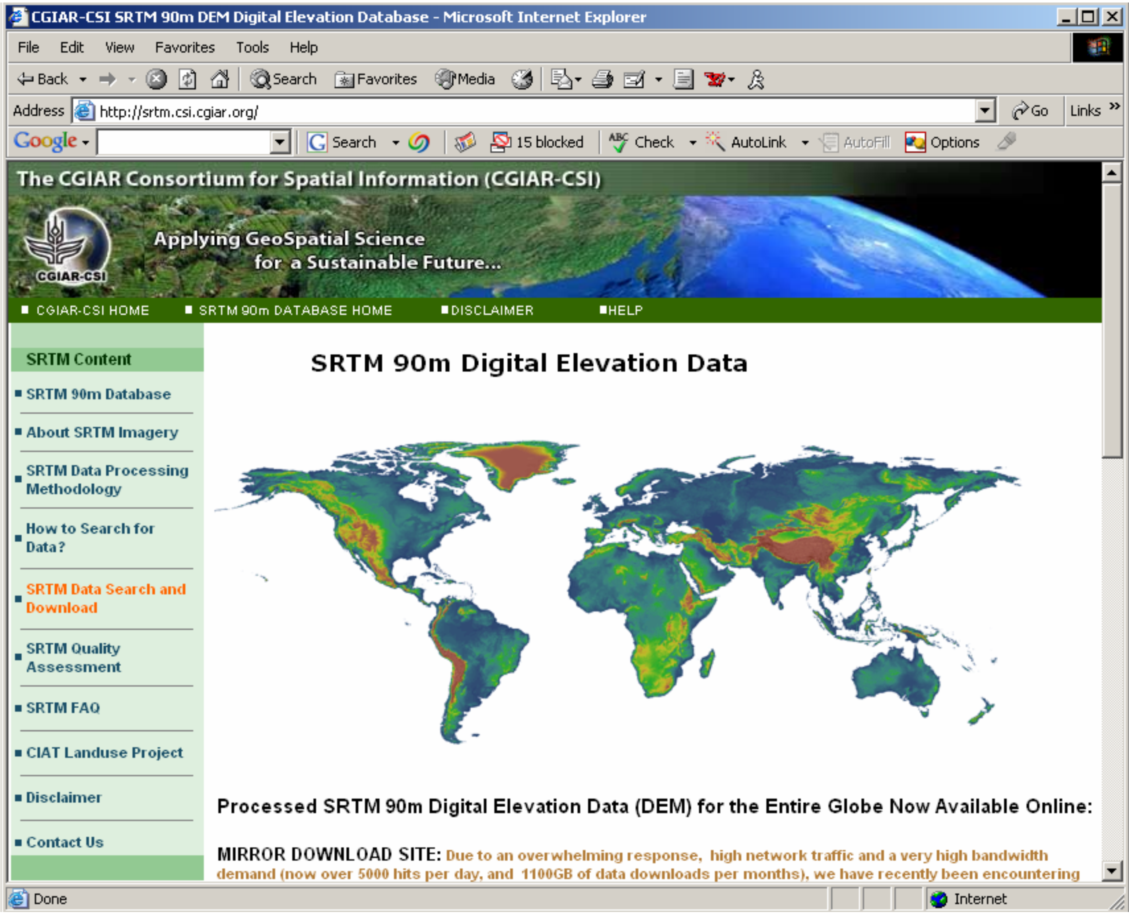
Two radar data sets were collected at the same time separated by 60 m, the distance between the main antenna and the outboard antenna. Knowing the distance between the two antennas and the differences in the reflected radar wave signals, accurate elevation of the Earth's surface was calculated.

There are several sources available from which you can obtain the SRTM data, including:

NASA (raw data): ftp://e0mss21u.ecs.nasa.gov/srtm/
USGS (somewhat corrected data): http://seamless.usgs.gov/
CGIAR (NoData holes filled): http://srtm.csi.cgiar.org/

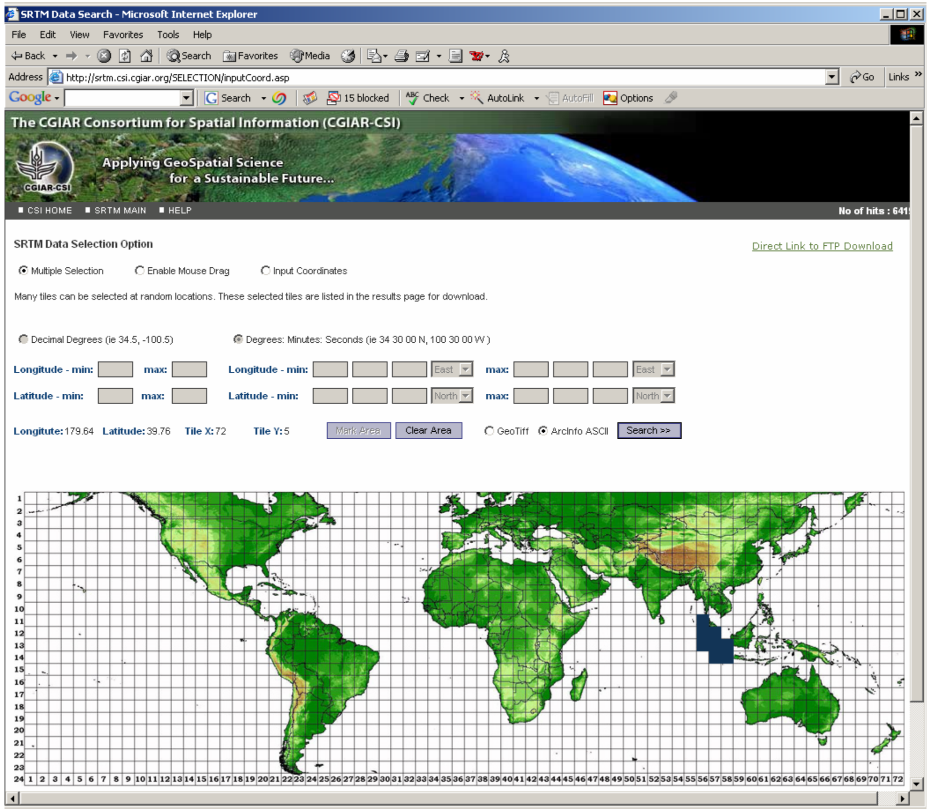
*Note: The **CGIAR** site is probably the best source of data since all of the No-Data holes are filled and the data are ready for use. However, they are not provided in a "seamless" format and several tiles must be downloaded for the designated area and then joined using the mosaic function.*

- Create a new folder in your **Participant** folder and name it **ASC Files**.
- Navigate to the **CGIAR** web site



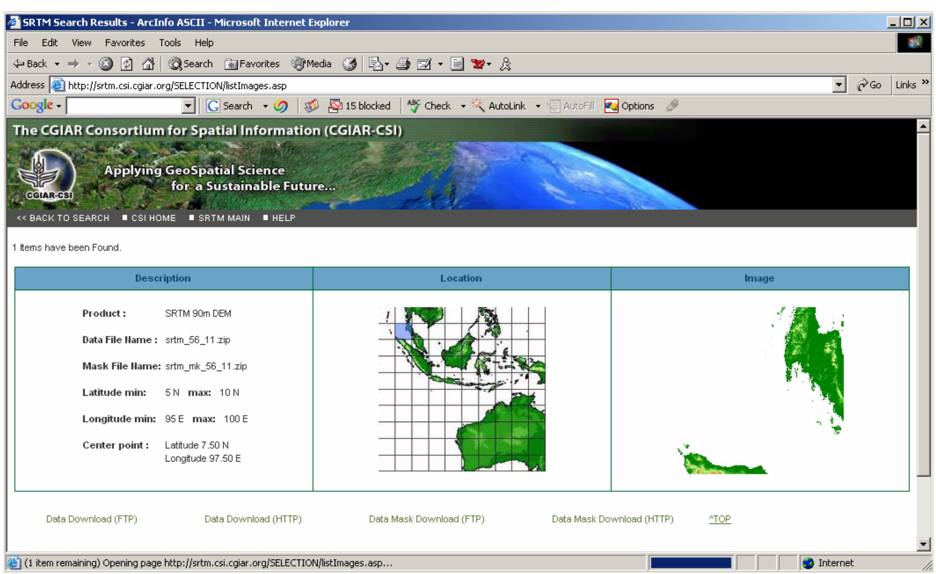
- Click **SRTM Data Search and Download** on the sidebar of the screen.
- Enter the Latitude and Longitude of your choice (if known) or highlight the tiles covering the focus area. For our purposes, select the tiles covering the island of Sumatra (*srtm_56_11*, *srtm_56_12*, *srtm_56_13*, *srtm_57_12*, *srtm_57_13*, *srtm_57_14*, *srtm_58_13*, *srtm_58_14*).

- Select the **ArcInfo ASCII** option and click **Search**.

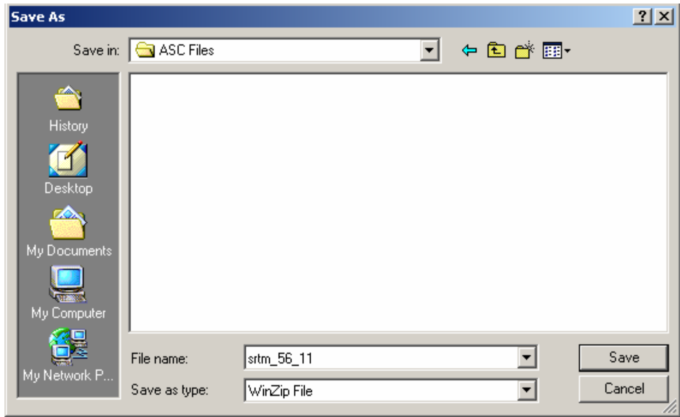


*Note: Alternatively, you can select **Direct Link to FTP Download**, select your tiles, and download all of the tiles at once.*

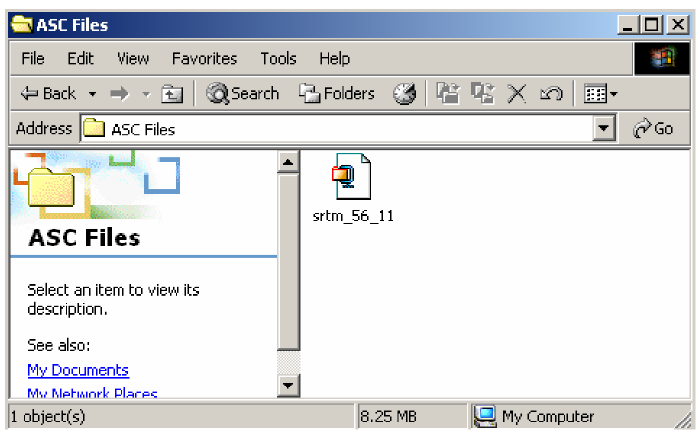
- A screen will appear showing all of the data tile information you selected.
- Click on **Data Download (FTP)** at the bottom of the page.



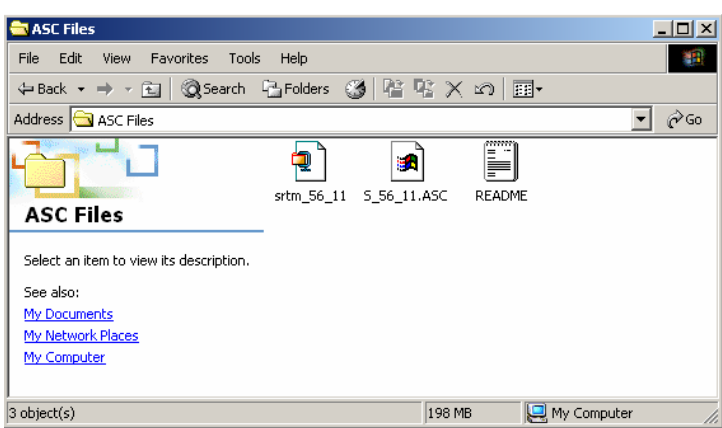
- Click **Save** and navigate to the **ASC Files** folder. Click **Save**.



- The tile data will be saved as a zip file into the **ASC Files** folder. Repeat this process to download zip files for all eight tiles covering the focus area. This can take up to **60 minutes**, depending on the speed of your internet connection.

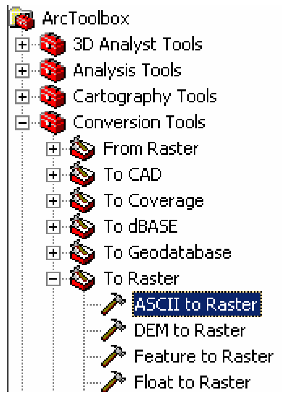


- Unzip the files for all eight tiles and select the **ASC Files** folder as the download location.

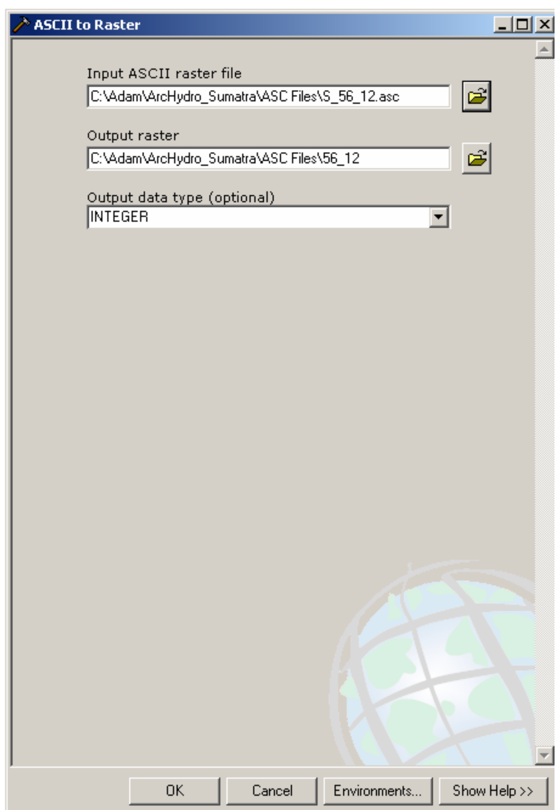


2.1.2 Convert SRTM Data to Raster Grids

- Open **ArcMap** and then open the **ArcToolbox**  from the standard toolbar menu.
- In the ArcToolbox, go to **Conversion Tools / To Raster / ASCII to Raster**.

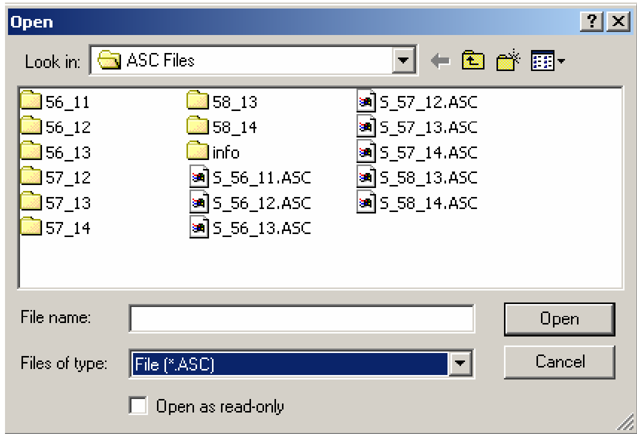


- Navigate to and select the first tile as the *Input ASCII raster file* and give it a unique name for the *Output raster*. Select **Integer** for the *Output data type* and click **OK**.

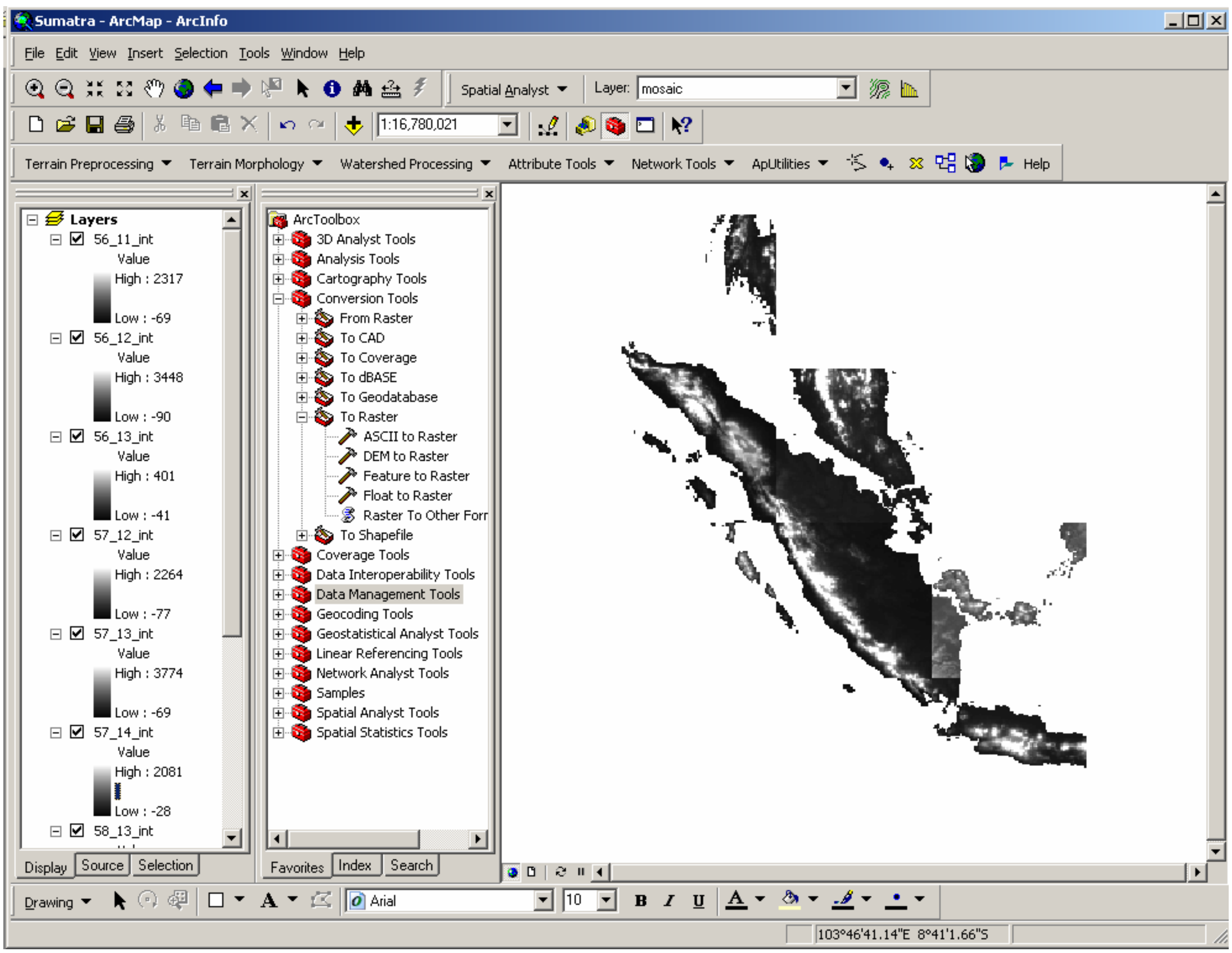


- Repeat this procedure for **each** tile until they have all been added to ArcMap as rasters.

- Your **ASC Files** folder will have a folder added for each tile once complete.



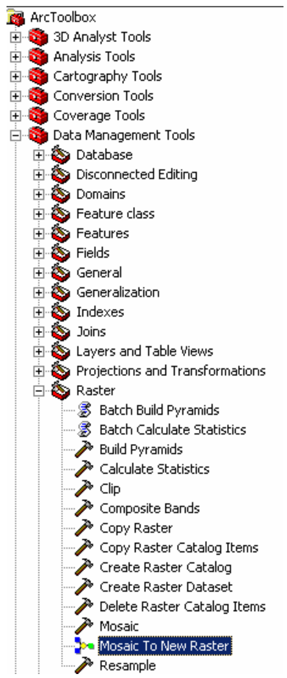
- The tiles will appear in ArcMap as shown below.



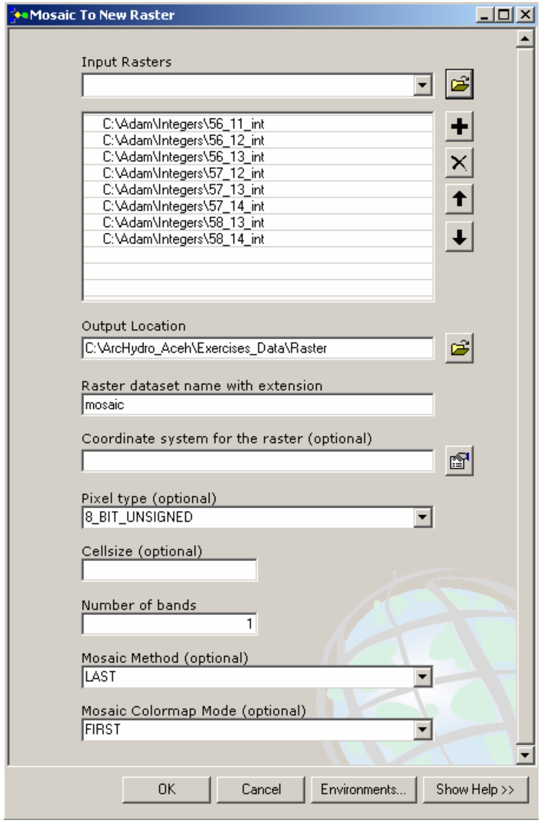
2.2 Mosaic Rasters

Multiple tiles need to be combined or mosaiced together into a larger grid. This can be done through the **Mosaic** function in ArcMap or ArcCatalog, or through the **Merge** function in Arc.

- Create a new folder in your **Participant** folder and name it **Rasters**.
- In ArcMap / ArcCatalog, open **ArcToolbox / Data Management Tools / Raster / Mosaic_to_New_Raster**



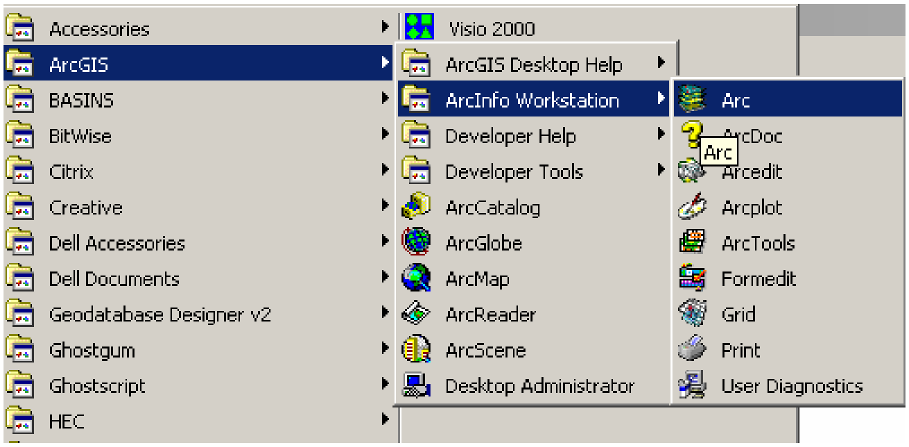
- Navigate to the **ASC Files** folder and select the rasters for all eight tiles as the *Input Rasters* field. Select the **Rasters** folder as the *Output Location* and name the new raster **mosaic**. Click **OK**.



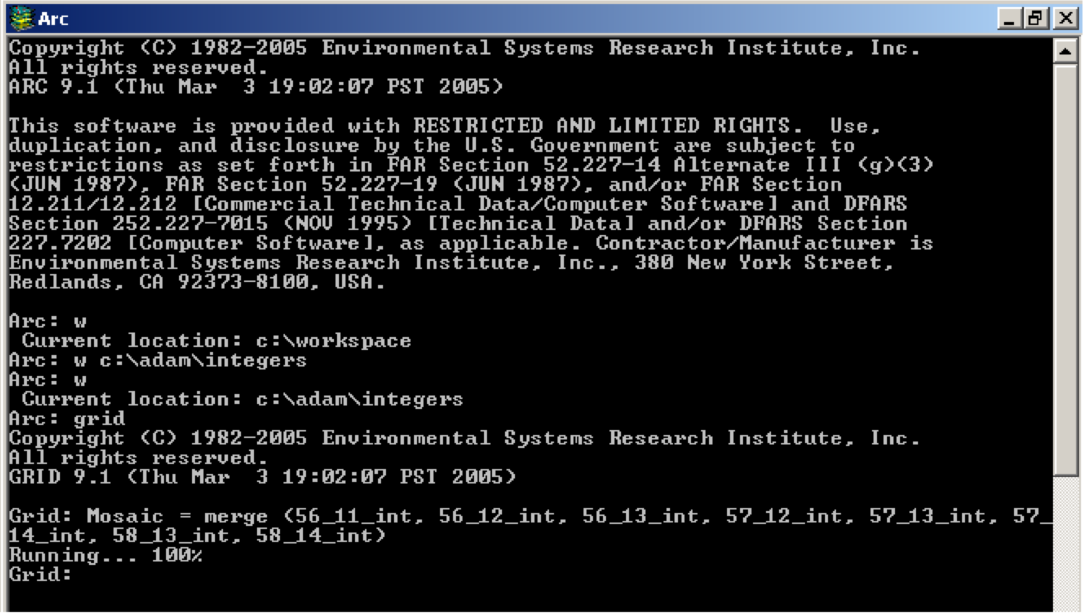
- This can take up to **30 minutes** depending on the computer you are using. Add the resulting DEM to the display to have a single tile for the whole region.

An alternate method to combine the tiles that is faster and also allows for "no data" holes to be filled is to use the **merge** function in **Arc**.

- On your desktop, go to **Start** / **Programs** / **ArcGIS** / **ArcInfo Workstation** / **Arc**.

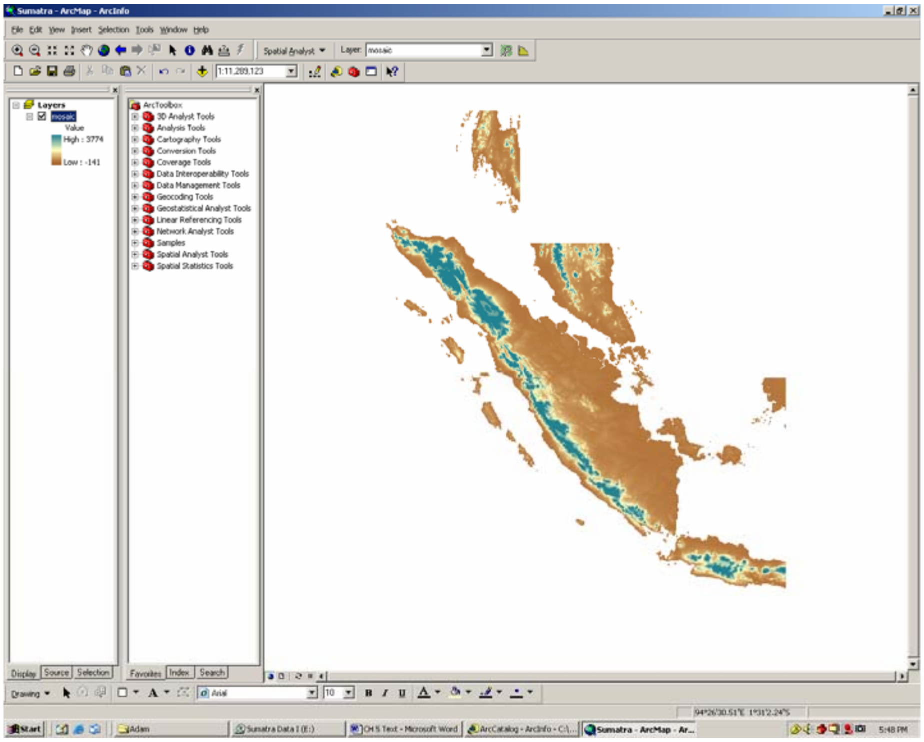


- **Arc** will prompt you for code input. After the first prompt (Arc:), type “**w**” (and then hit **Enter**). After the next prompt, type “**w**” followed by the **path to the folder with the tile raster data**. Type “**w**” again after the next prompt and then “**grid**” after the next. Finally, type “**Mosaic = merge (enter all of the tile raster names)**” and click **Enter**.



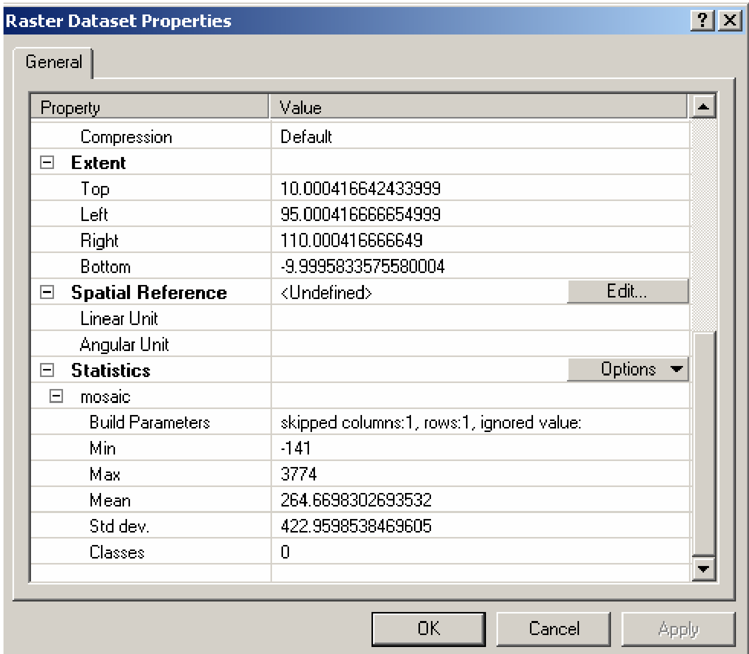
Note: Spaces in names (i.e. ASC Files) in the pathline may have to be removed to avoid errors

- Either method will produce a single **mosaic** raster that covers the entire focus area.

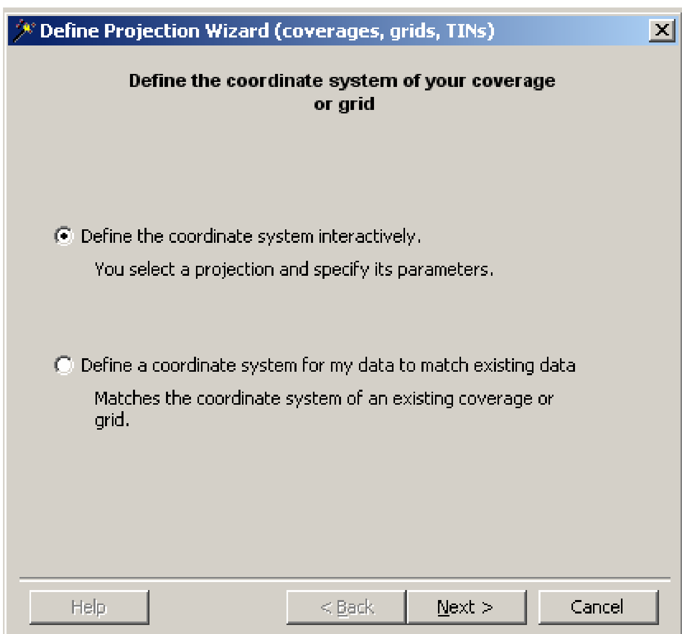


2.3 Define the Spatial Reference for Grids

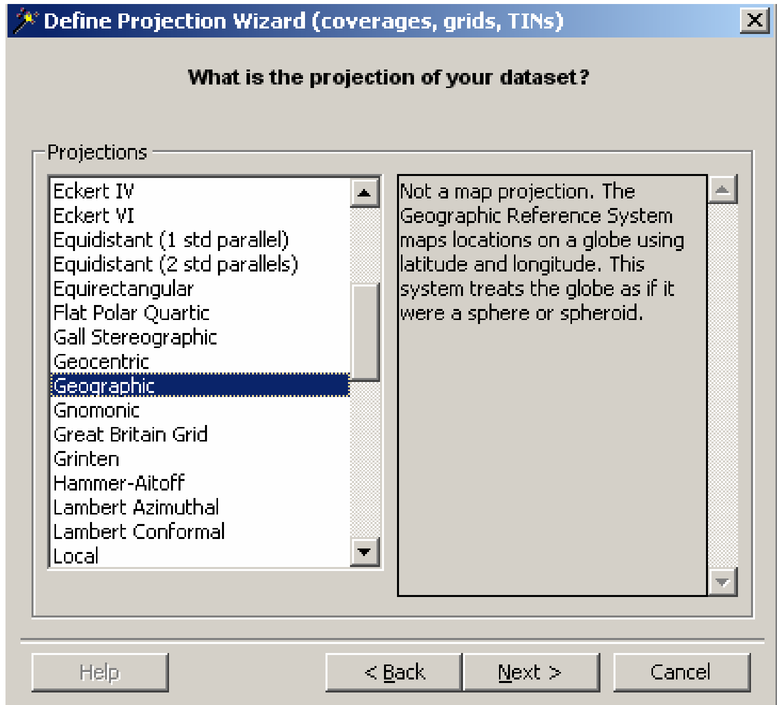
- Close ArcMap and open **ArcCatalog** to define the **Spatial Reference** of the **mosaic** raster.
- Right click on the **mosaic** raster icon and select **Properties**. Scroll down to **Spatial Reference**. Click the **Edit** button.



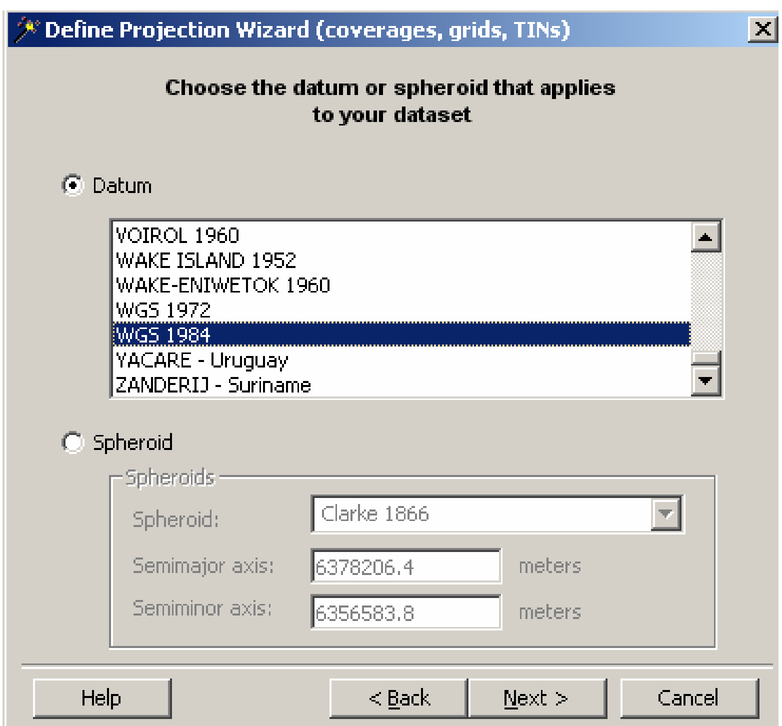
- Select *Define the coordinate system interactively*. Click **Next**.



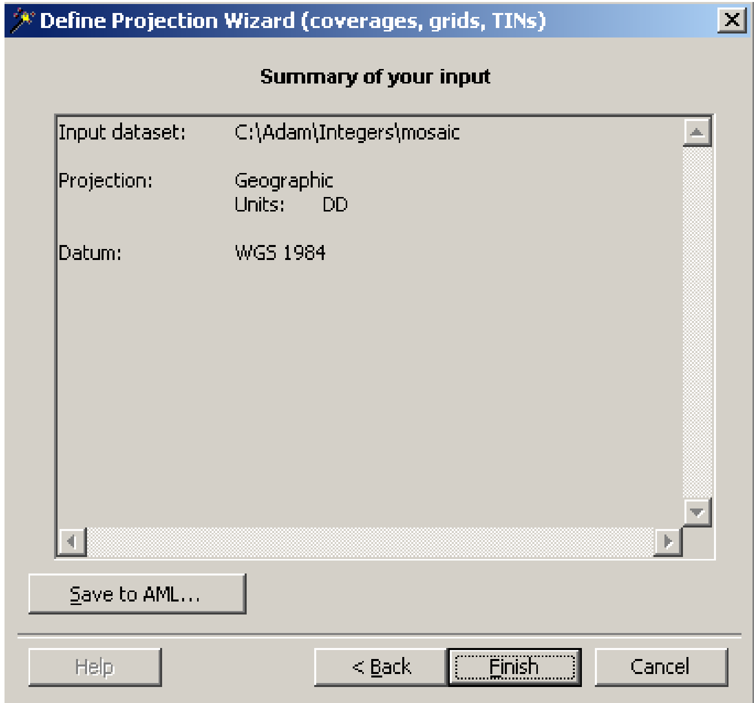
- Select the **Geographic** projection and click **Next**.



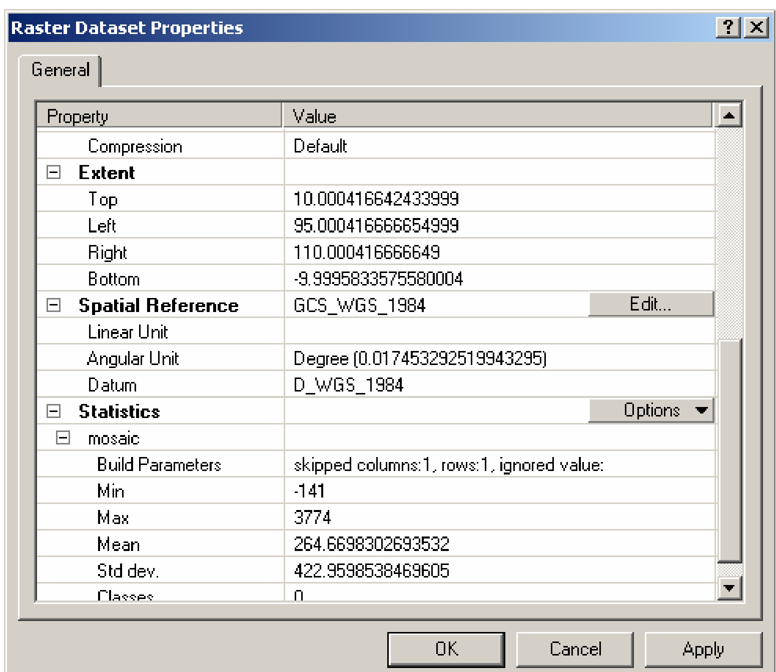
- Select **decimal degrees** (DD) and click **Next**.
- Select **WGS-1984** datum and click **Next**.



- Make sure the proper *Projection* and *Datum* are shown and click **Finish**.



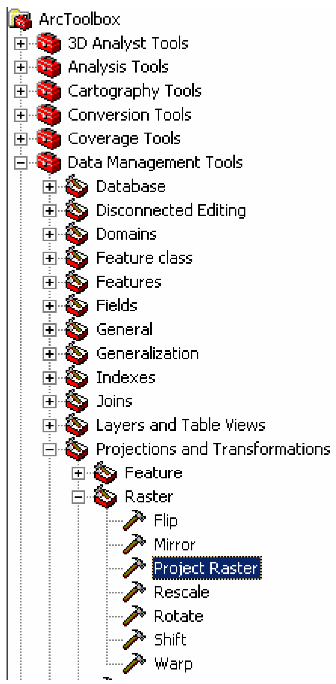
- Note that a *Spatial Reference* and *Datum* are now defined in the **Properties** of the **mosaic** raster. Click **OK**.



2.4 Project Grids

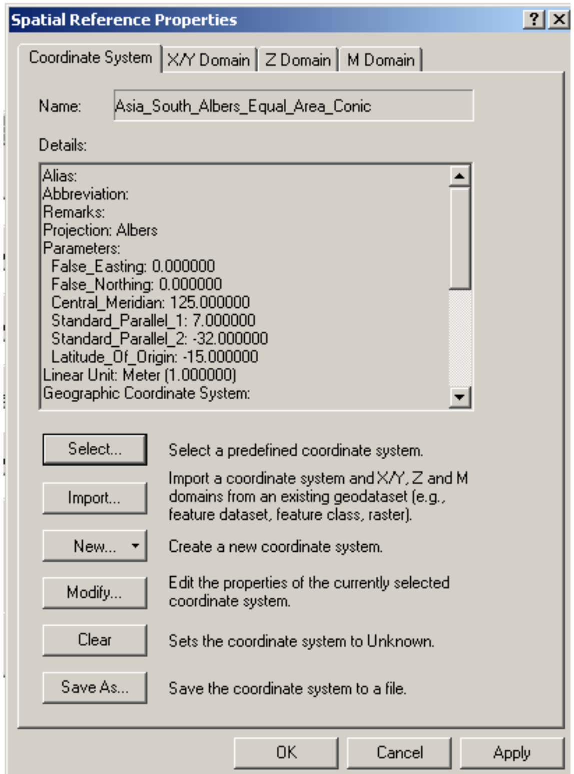
The mosaic raster needs to be projected into the working projection with appropriate cell size.

- Open **ArcMap** or **ArcCatalog** and then open **ArcToolbox**.
- In ArcToolbox, open **Data Management Tools / Projections and Transformations / Raster / Project Raster**

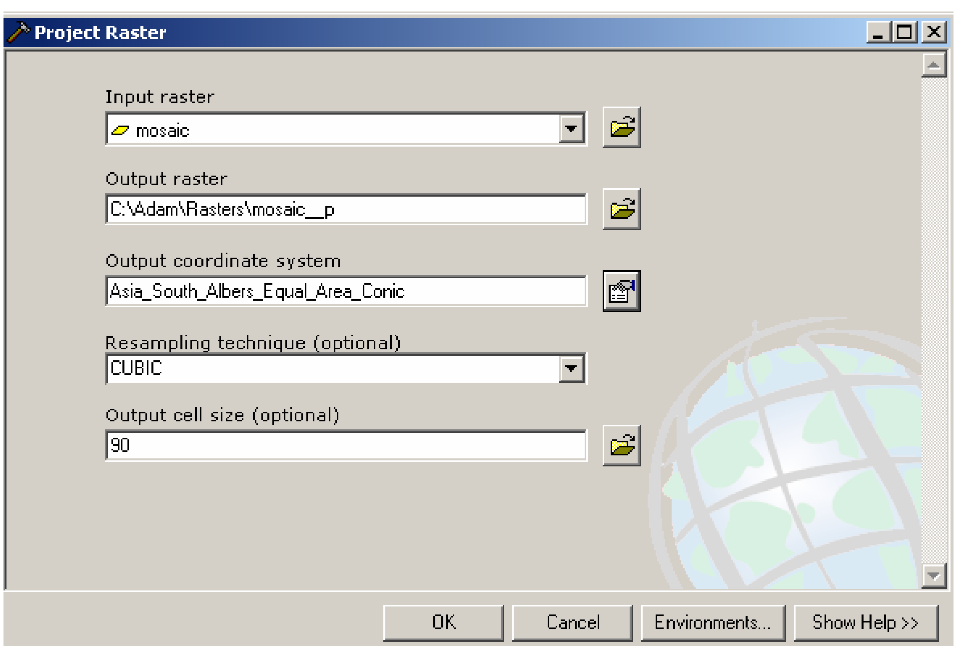


- Select the **mosaic** raster as the *Input raster* and give it the name **mosaic_p** for the *Output raster*.

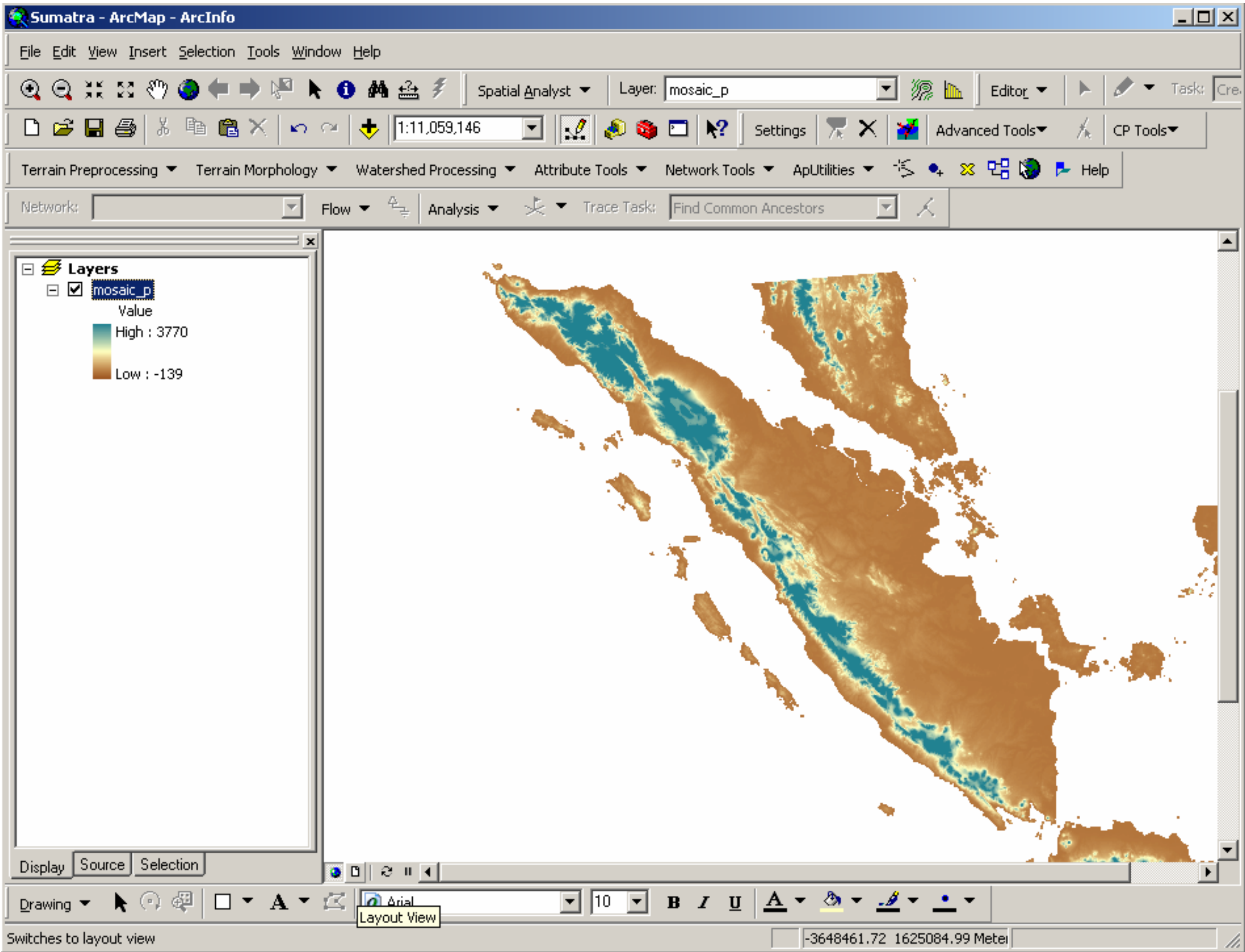
- Click on the  icon for the *Output coordinate system*. Click the **Select** button and choose the following navigational path: **Projected Coordinate Systems / Continental / Asia / Asia South Albers Equal Area Conic**. Click **OK**.



- Select **Cubic** for the *Resampling technique* and **90** as the *Output cell size*. Click **OK**.



- Open **ArcMap** and add the new raster projection (the raster will take **15-20 minutes** to project).



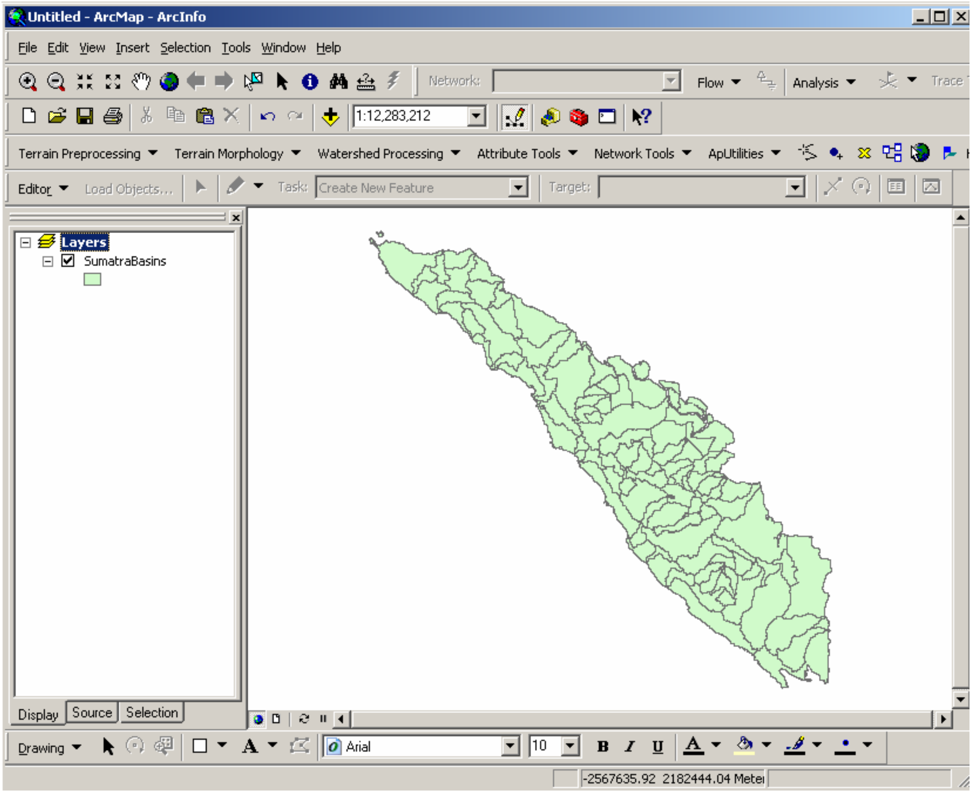
3. Data Preprocessing

3.1 Make Buffer for the Basin

3.1.1 Create Basin Feature Class

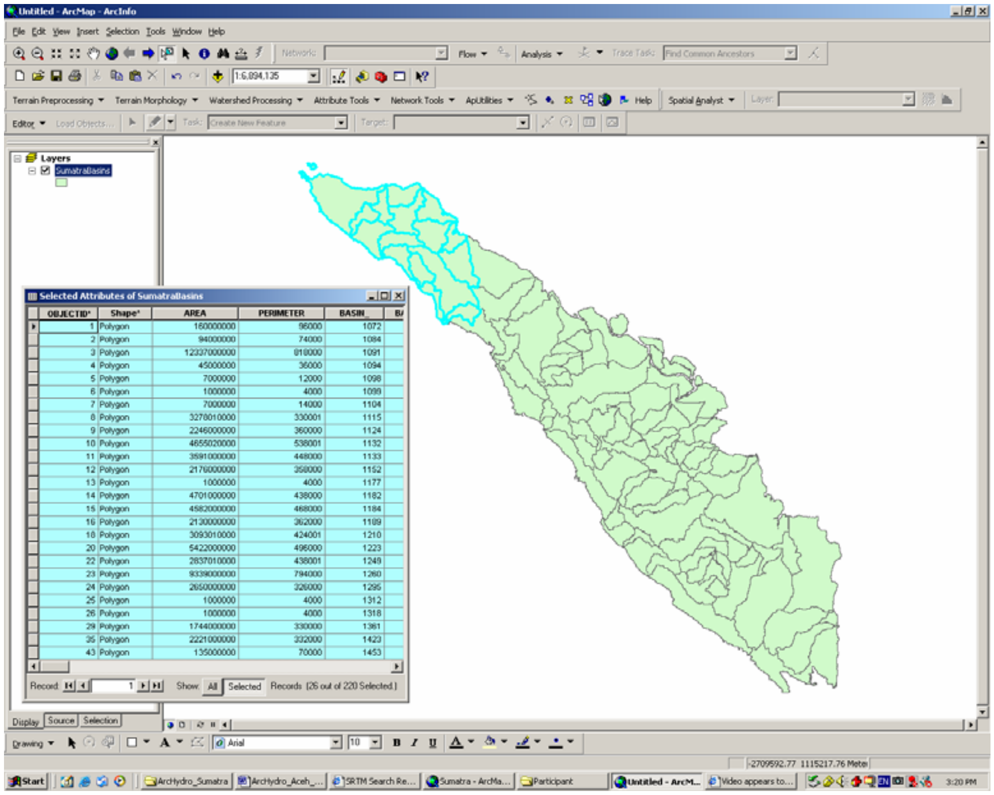
Objective: Create a feature class for the Aceh River basin

- Open ArcMap. Add the **SumatraBasins** feature class from the **Aceh** geodatabase.

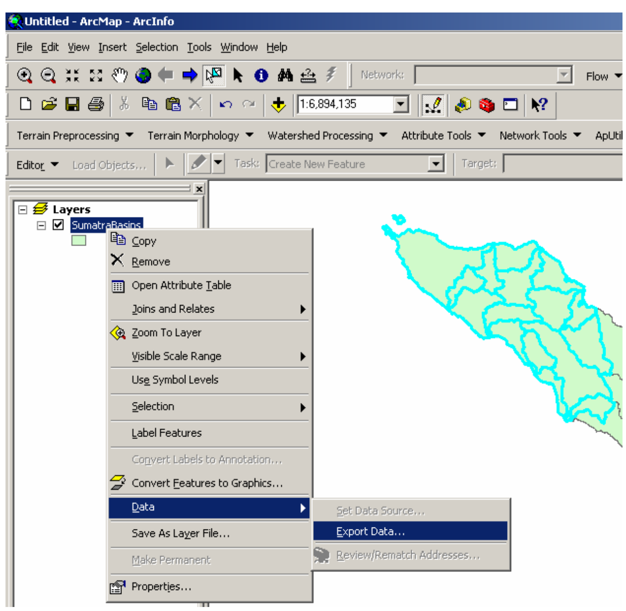


- Click on the **Select** button  in the main toolbar. Hold down the left button of your mouse and draw a box around the northern third of the island of Sumatra. All of the basins in the northern third of the island should now be highlighted

- Right click on the **SumatraBasins** layer and choose **Open Attribute Table**. Click the **Selected** button at the bottom of the window. This will show you the items you have selected (you should have 26 out of 220 items selected).

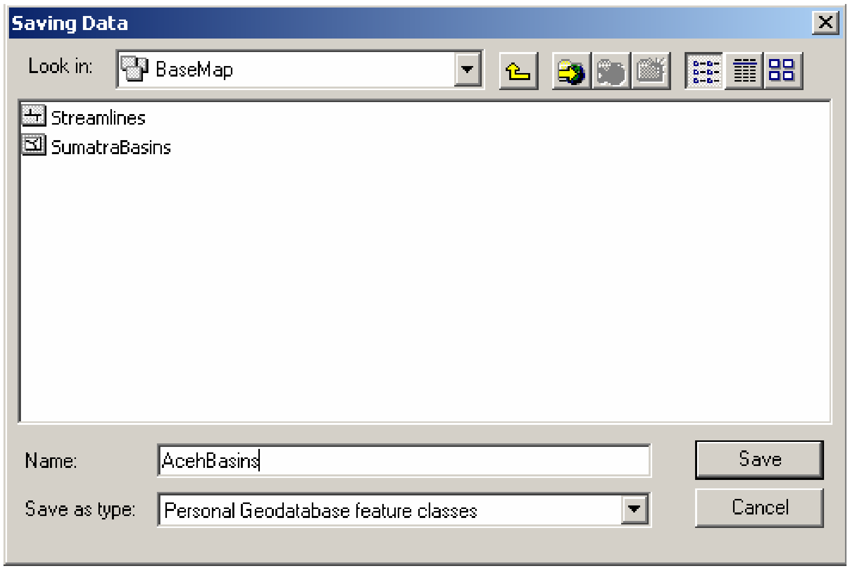


- Make sure that **Arc Catalog** is closed or else the following steps will not work.
- Close the attribute table and right click on the **SumatraBasins** layer. Select **Data / Export Data ...** to produce a new layer.



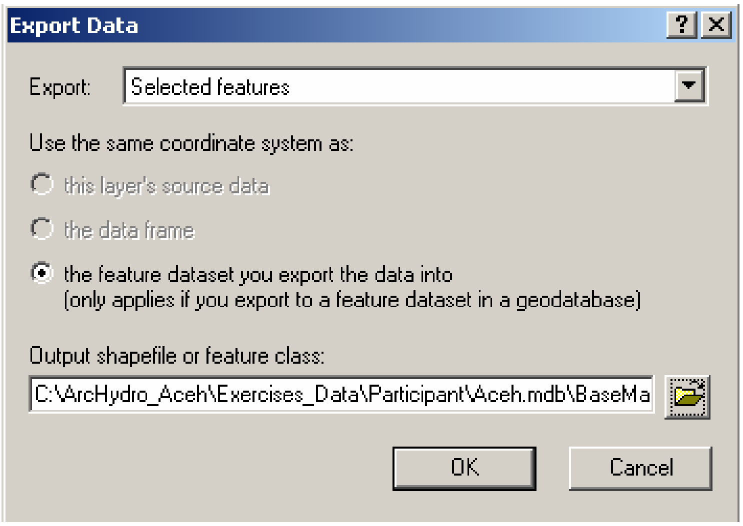
- In the *Output shapefile or feature class* window, navigate inside the **Aceh** geodatabase to the **BaseMap** feature dataset. Name this new feature class **AcehBasins** and click **Save**.

*Note: By assigning Arc Hydro standard names like **AcehBasins** to your feature classes it will be easier to apply the capabilities of the ArcHydro data model as you will see later in this class (See page 32 in Arc Hydro book for standards).*

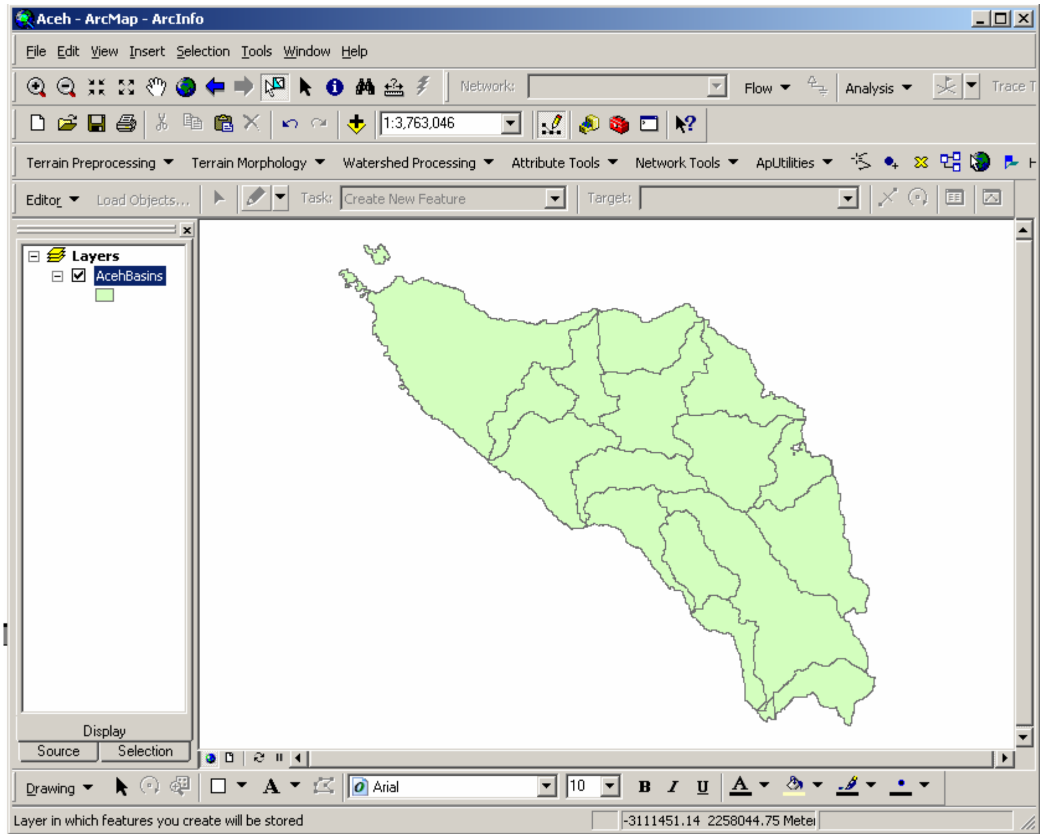


- Click **OK** to export selected features to a new **AcehBasins** feature class. The program will automatically convert only the selected features.

*Note: If you get a message saying this can't be done, it means that you have not shut down Arc Catalog before exporting data. Close **Arc Catalog** and repeat the export steps if this happens.*



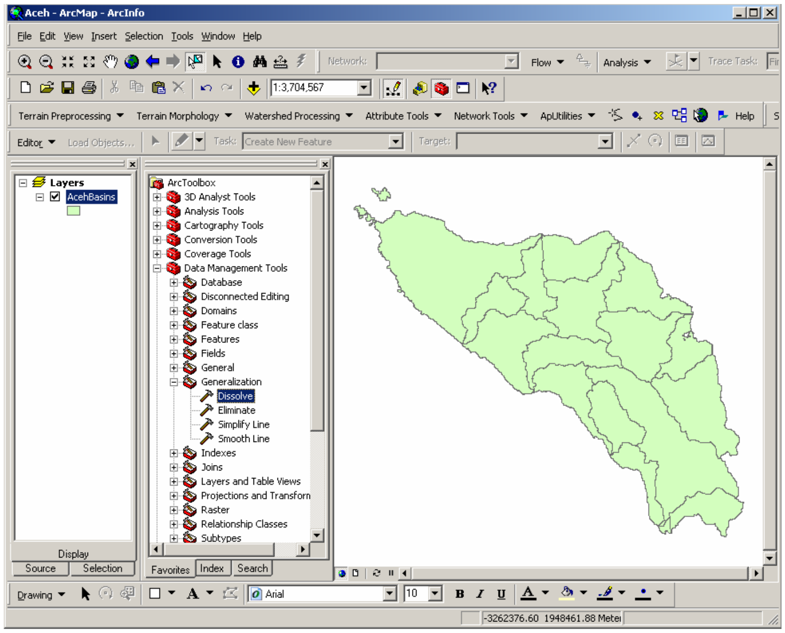
- Click **Yes** when asked if you would like to add this theme to the map. Notice the **AcehBasins** feature class carries the attributes of **SumatraBasins** before the data export.
- Use **Selection / Clear Selected Features** to clear the selections made from **SumatraBasins**.
- Remove the **SumatraBasins** feature class from the map and zoom to the **AcehBasins** layer.
- Save the ArcMap document as **Aceh**.



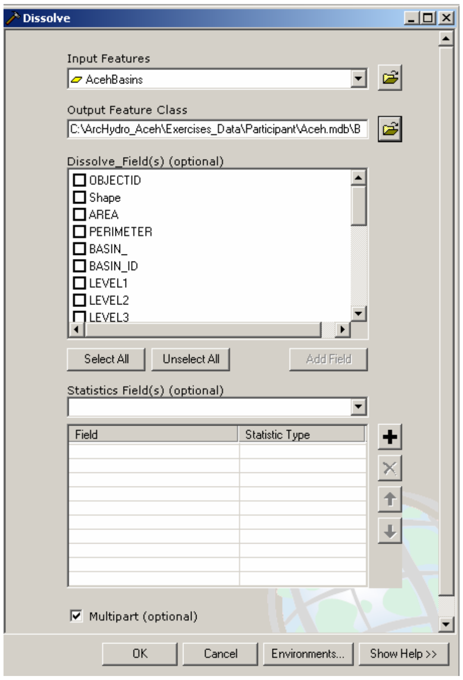
3.1.2 Dissolve Basins in a Feature Class

Objectve: Dissolve the basins of the AcehBasins feature class into one master basin

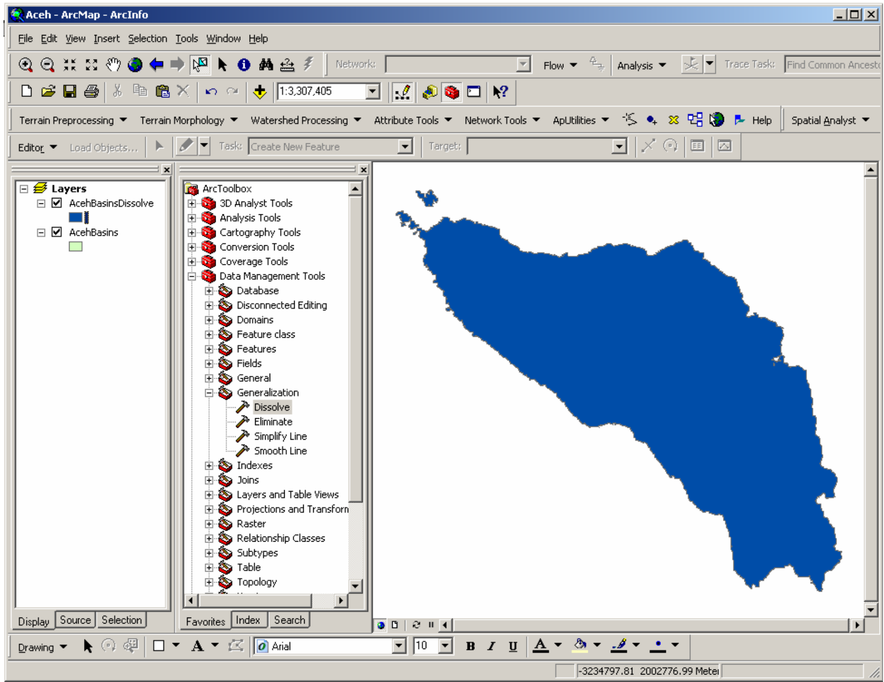
- Open the **ArcToolbox** application and go to **Data Management Tools / Generalization / Dissolve.**



- Select **AcehBasins** as the *Input features*. Navigate to the **BaseMap** feature dataset and name/save **AcehBasinsDissolve** as the *Output feature class*. Click **OK**.



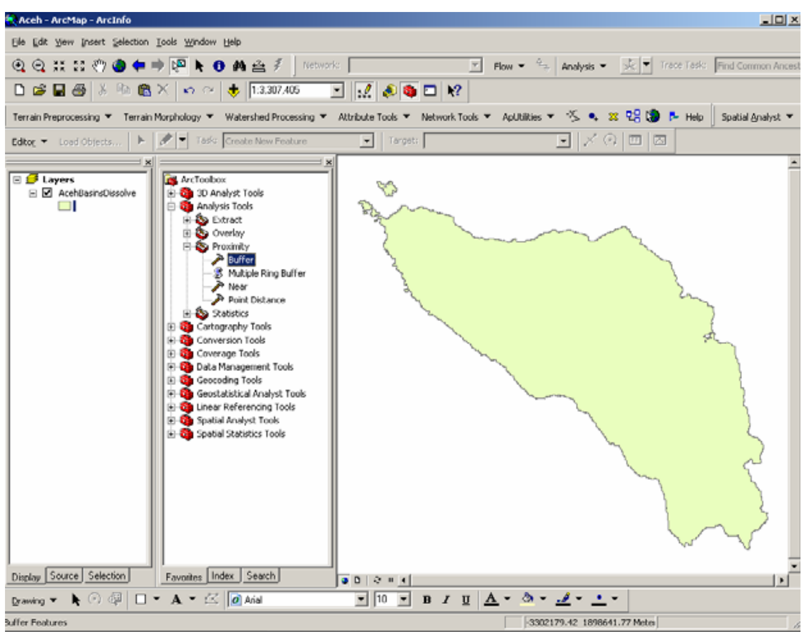
- The result is shown below. Remove the **AcehBasins** feature class from the map.



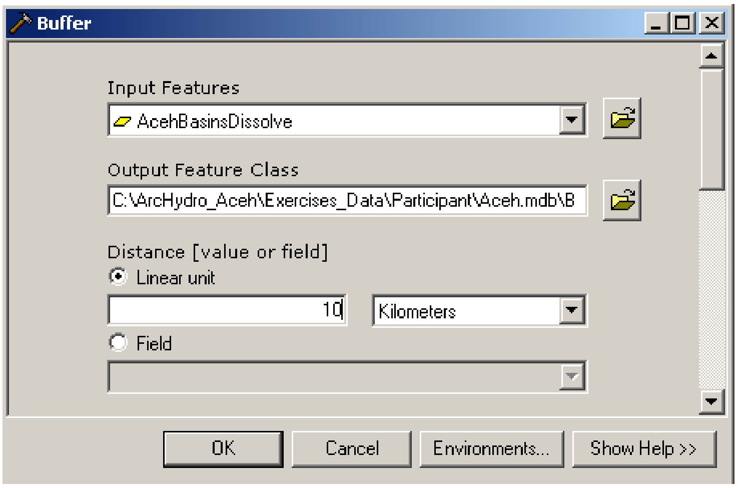
3.1.3 Create Basin Buffer

Objective: Create a 10 km buffer around the AcehBasinsDissolve feature class

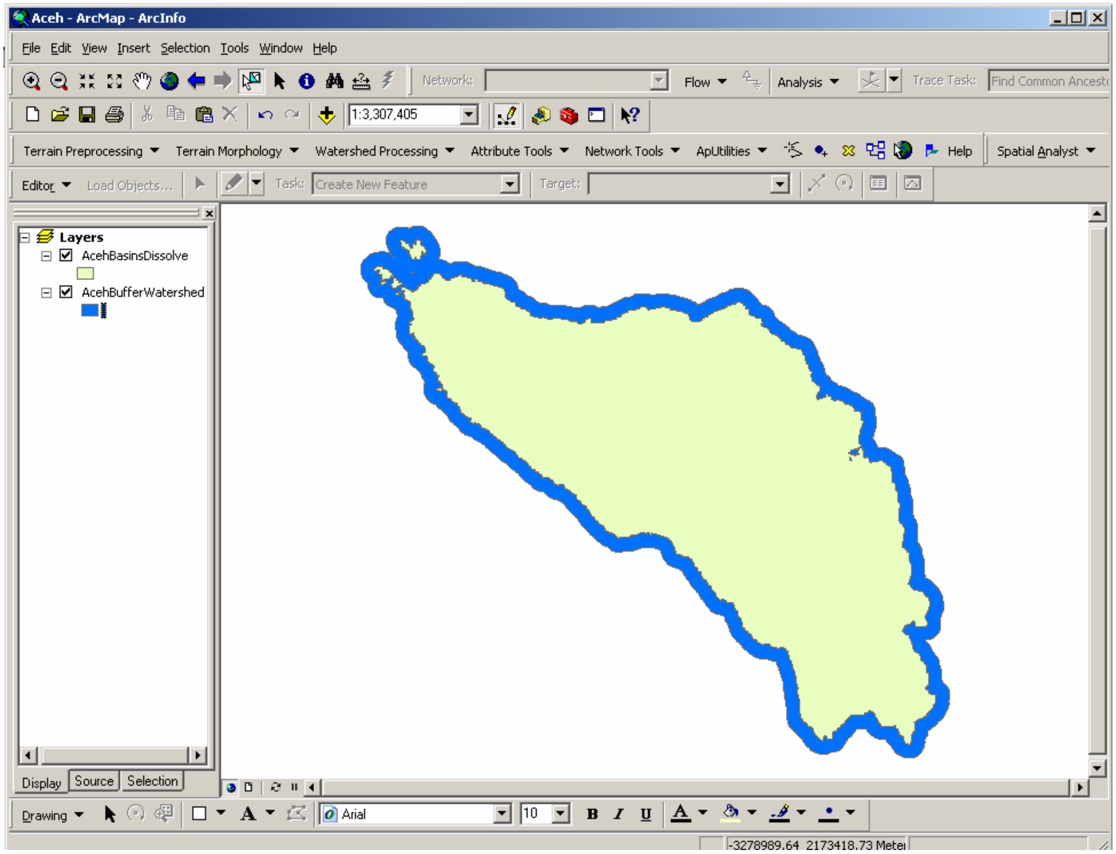
- In the **ArcToolbox** application, go to **Analysis Tools** / **Proximity** / **Buffer**.



- Select **AcehBasinsDissolve** as the *Input Feature*.
- Save **AcehBufferWatershed** as the *Output Feature Class* (in the BaseMap feature dataset of the Aceh geodatabase).
- Select **Linear unit** in the *Distance* field and specify a **10 km buffer**. Leave all remaining fields with their default values. Click **OK**.



- The result is shown below.

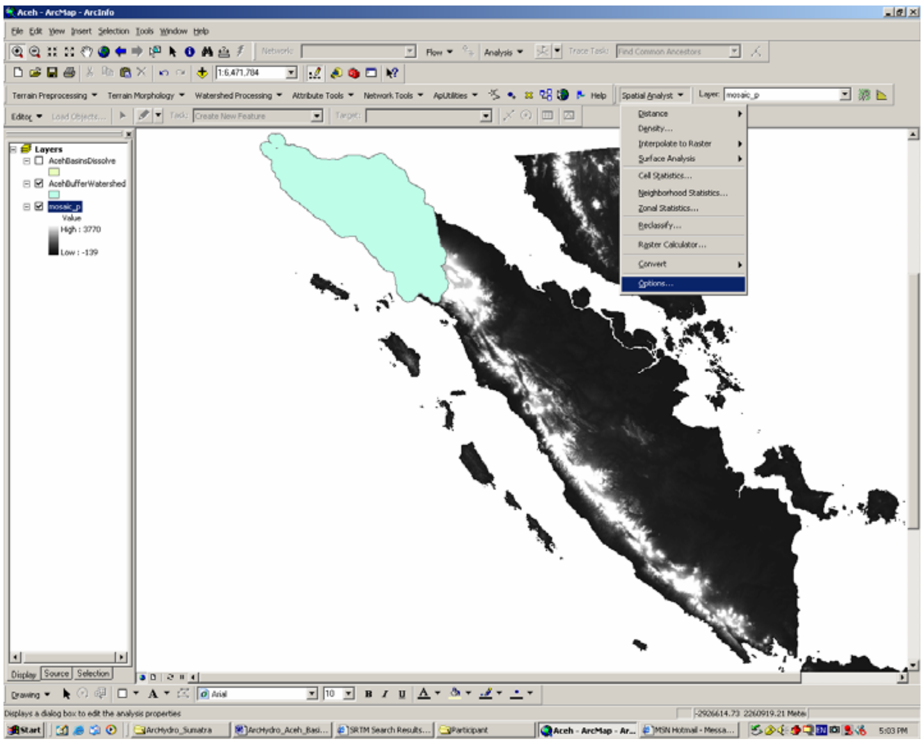


3.2 Clip Regional Grids to Basin with Buffer

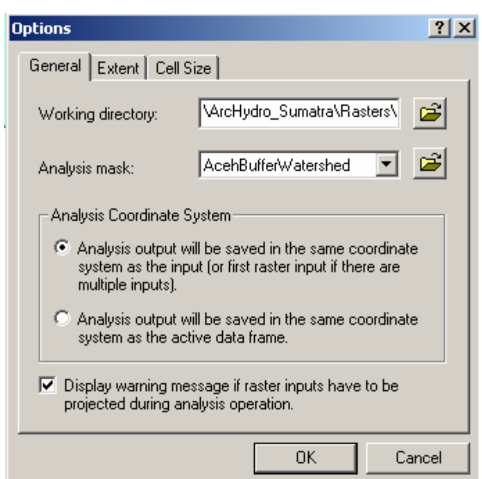
3.2.1 Set the analysis parameters

Objective: Establish extent, cell size, and masking parameters

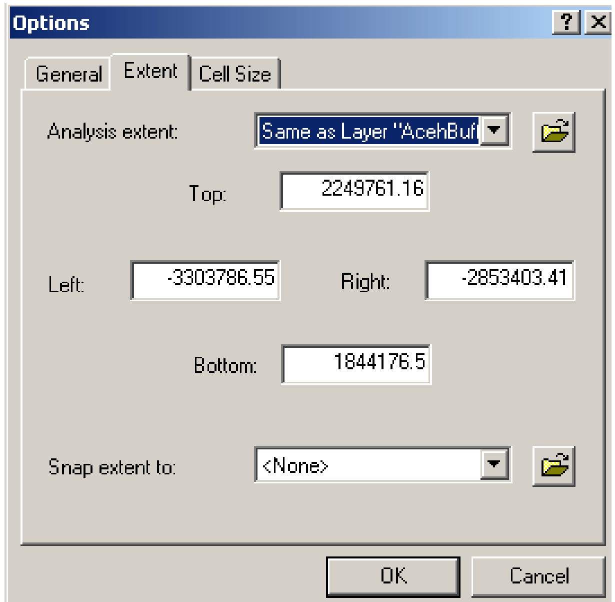
- Add the **mosaic_p** raster to the ArcMap document.
- Go to **SpatialAnalyst / Options** in the main toolbar.



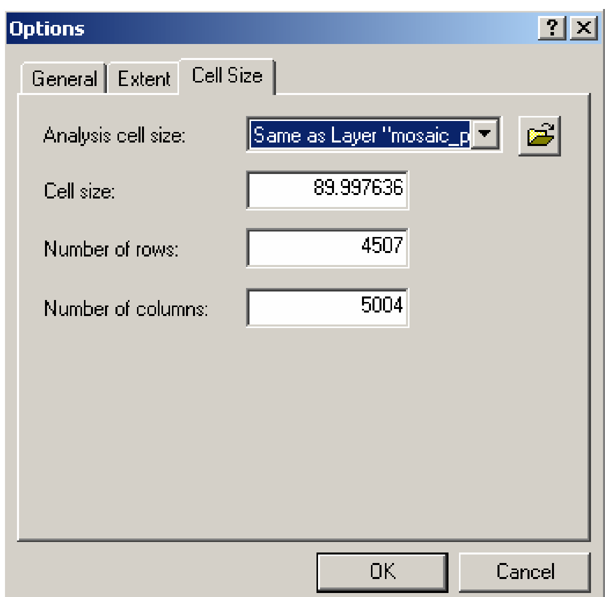
- Under the **General** tab, make sure the *Working Directory* is your **Rasters** folder and set the *Analysis Mask* to **AcehBufferWatershed**. Leave all other default settings unchanged.



- Click on the **Extent** tab and set the *Analysis Extent* to be the same as the **AcehBufferWatershed**.



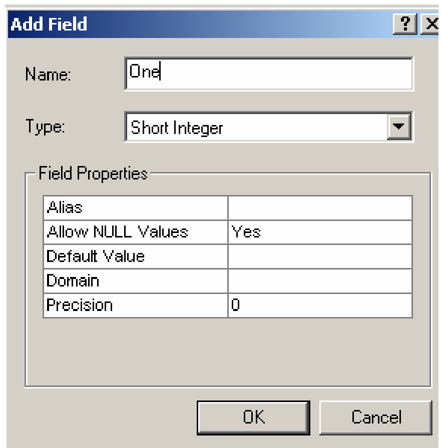
- Click on the **Cell Size** tab and set the *Analysis Cell Size* to be the same as the **mosaic_p** DEM. Click **OK**.



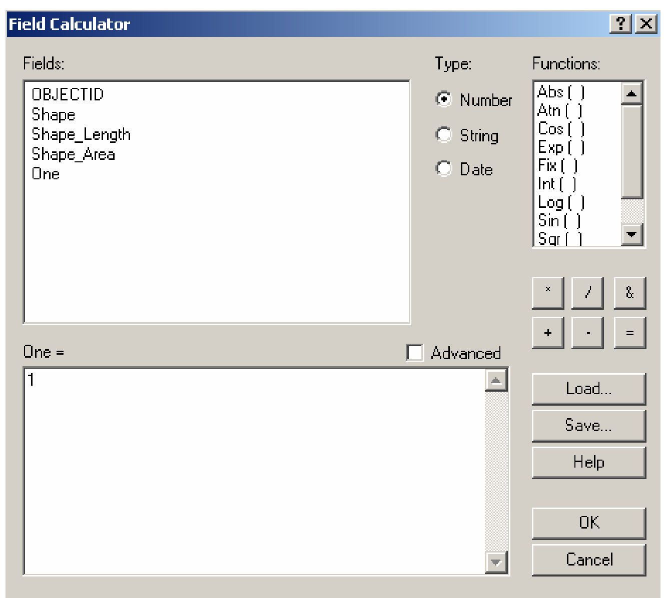
3.2.2 Convert Buffer to Raster

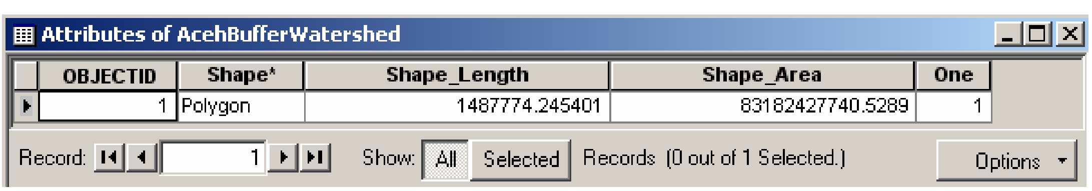
Objective: Convert the AcehBufferWatershed feature class to a raster

- Right click on the **AcehBufferWatershed** layer and click **Open Attribute Table**
- Click **Options** / **Add Field** at the bottom of the attribute table. Choose **One** for the *Name* and **Short Integer** for the *Type*. Click **OK**.

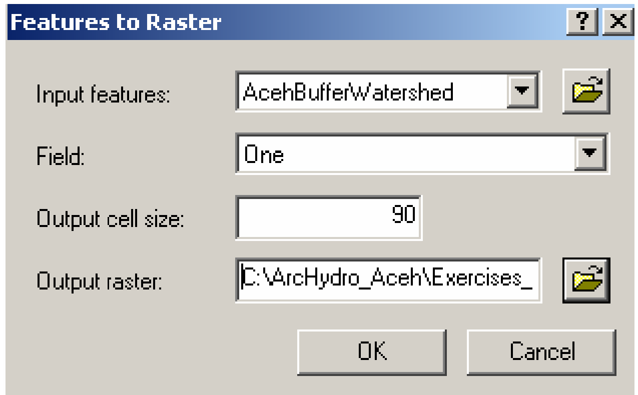


- Right click on the field **One** in the attribute table and select **Calculate Values**. Type "**1**" (Value of One = 1). Click **OK** and close the attribute table.

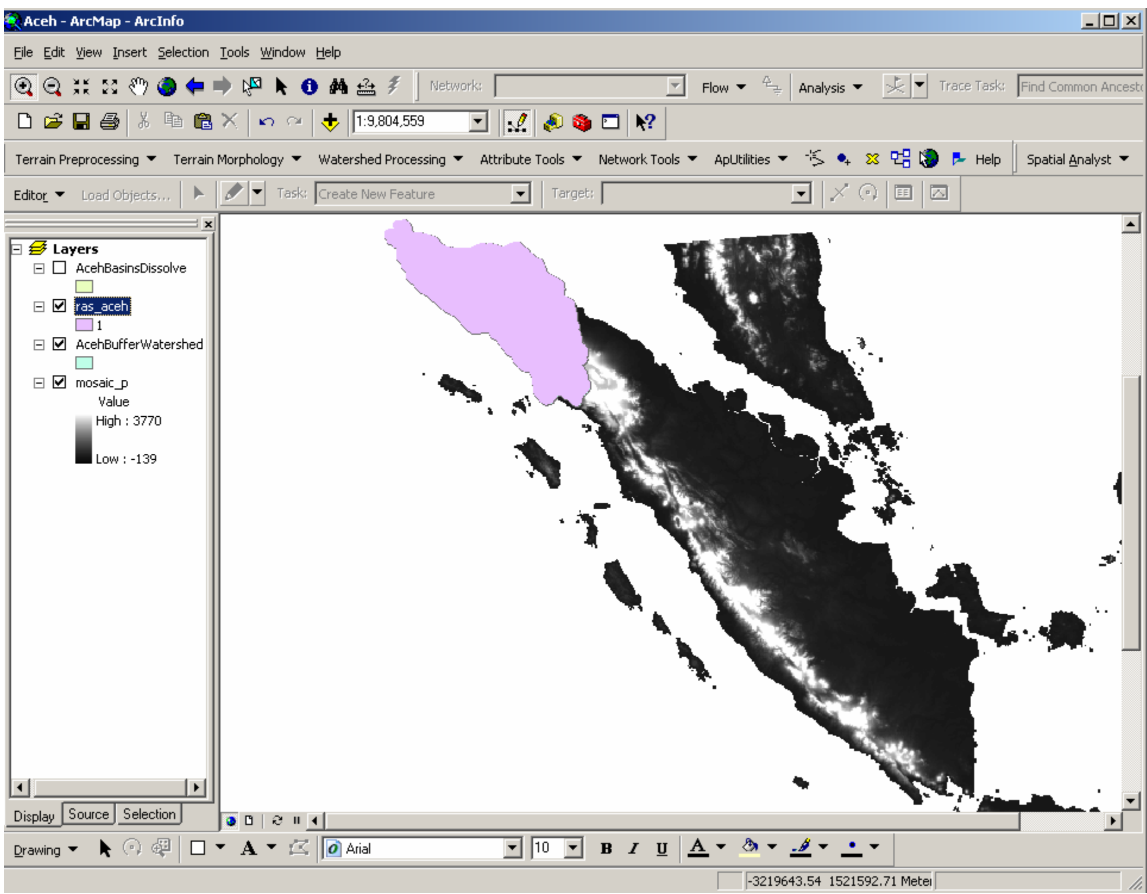




- Open **Spatial Analyst / Convert / Features-to-Raster.**
- Select **AcehBufferWatershed** for the *Input features*, **One** for the *Field*, **90** for the *Output cell size*, and **Ras_Aceh** for the *Output raster* (save in Raster folder).



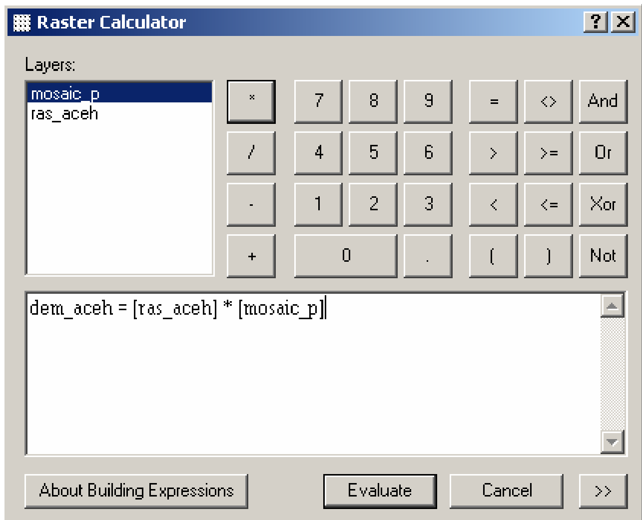
- The resulting **Ras_Aceh** raster covers the same area as the **AcehBufferWatershed** feature class.



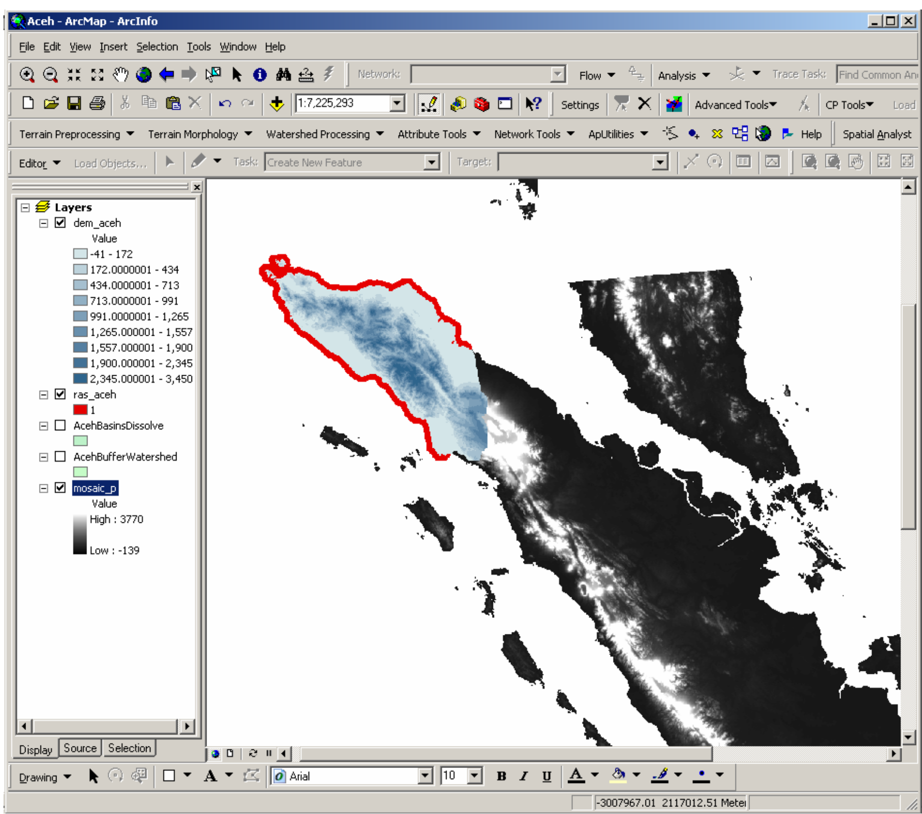
3.2.3 Clip DEM to Basin

Objective: Clip the projected mosaic DEM to the basin using the Aceh raster

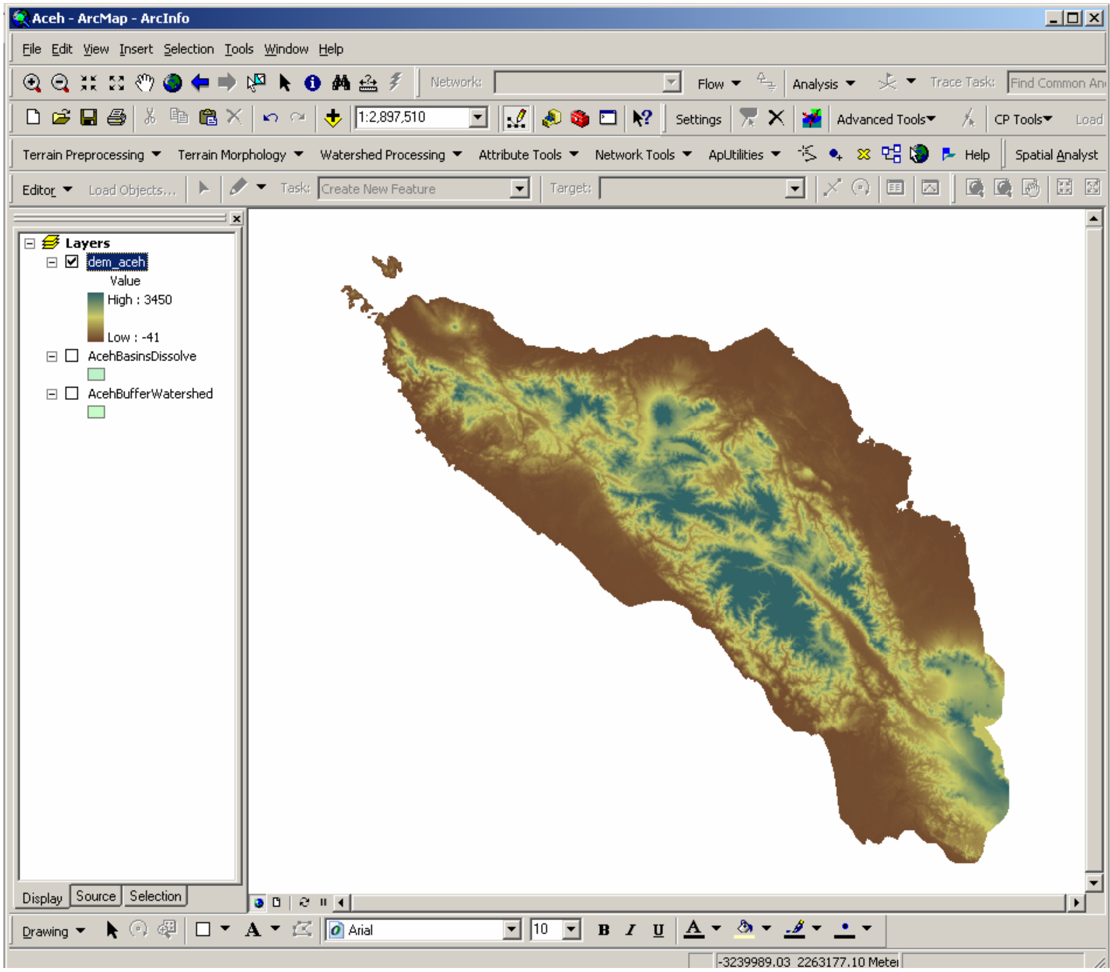
- Open **Spatial Analyst / Raster Calculator**. Clip the island DEM raster **mosaic_p** to the area of the **Ras_Aceh**. Click **Evaluate**.



- The result is:



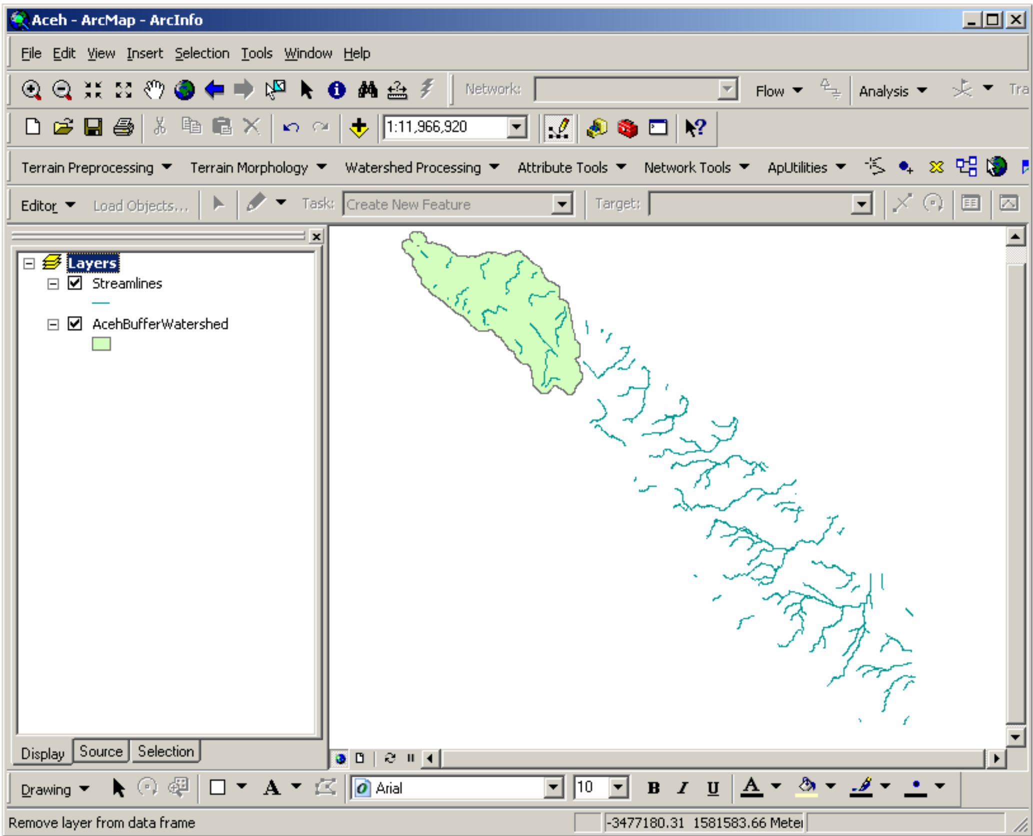
- The final result is the following figure.



3.3 Select Basin Flowlines

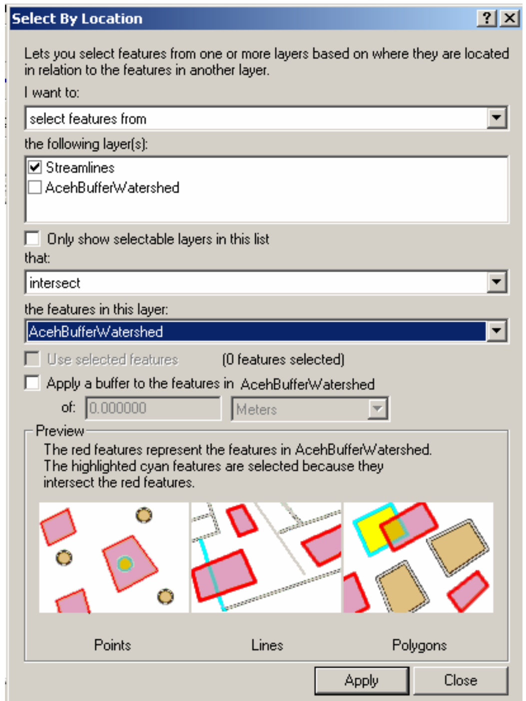
Select all the **Streamlines** lines that lie within this **AcehBufferWatershed** and export them to the **BaseMap** feature dataset as **AcehStreamlines**.

- Open the **Aceh** ArcMap document and add the **AcehBufferWatershed** and **Streamlines** feature classes.

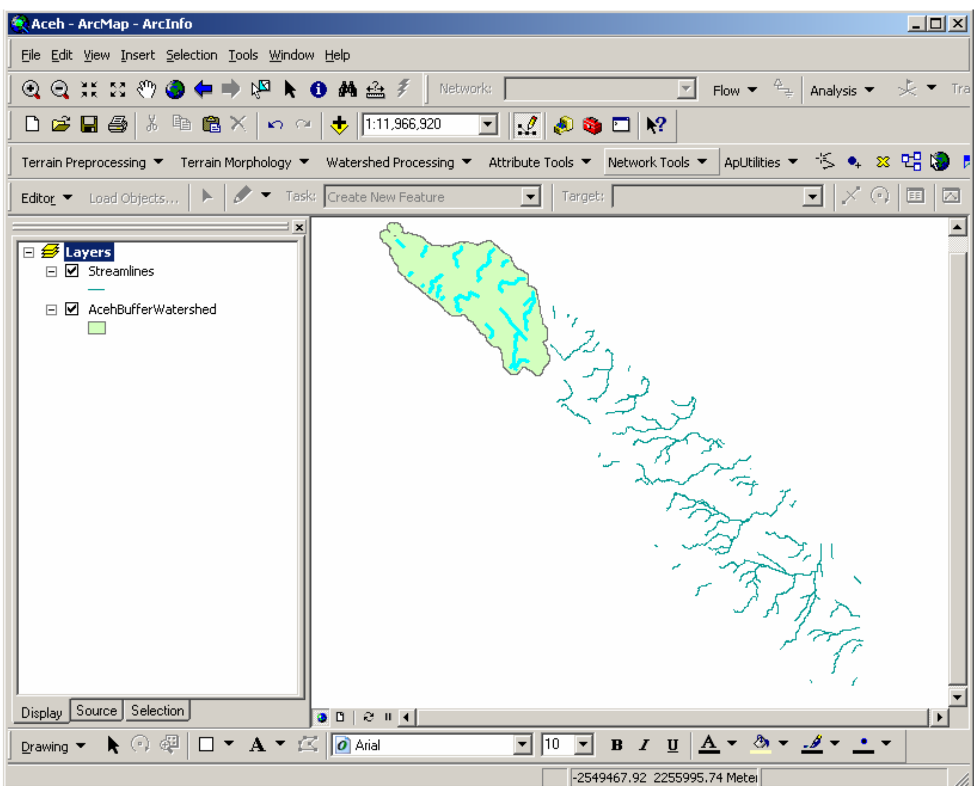


- In the main ArcMap menu, click on **Selection** / **Select by Location**.

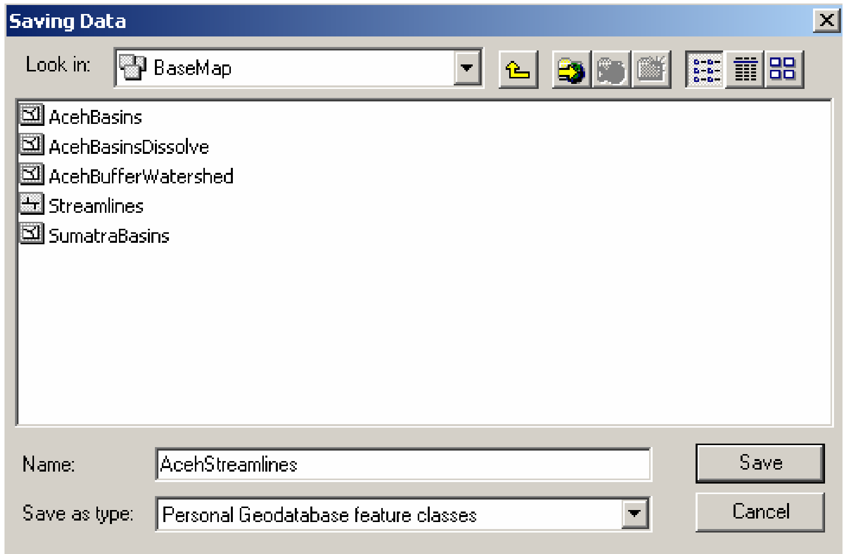
- Select features from the **Streamlines** layer that **intersect** the **AcehBufferWatershed** feature layer. Click **Apply** and **Close**.



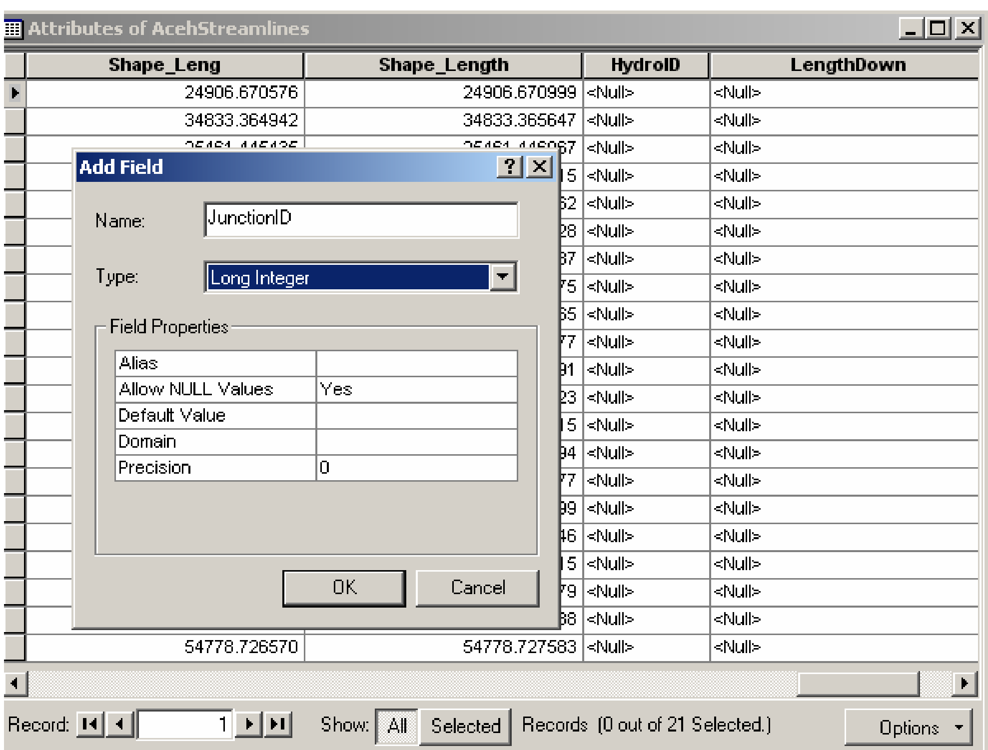
- The result is shown below:



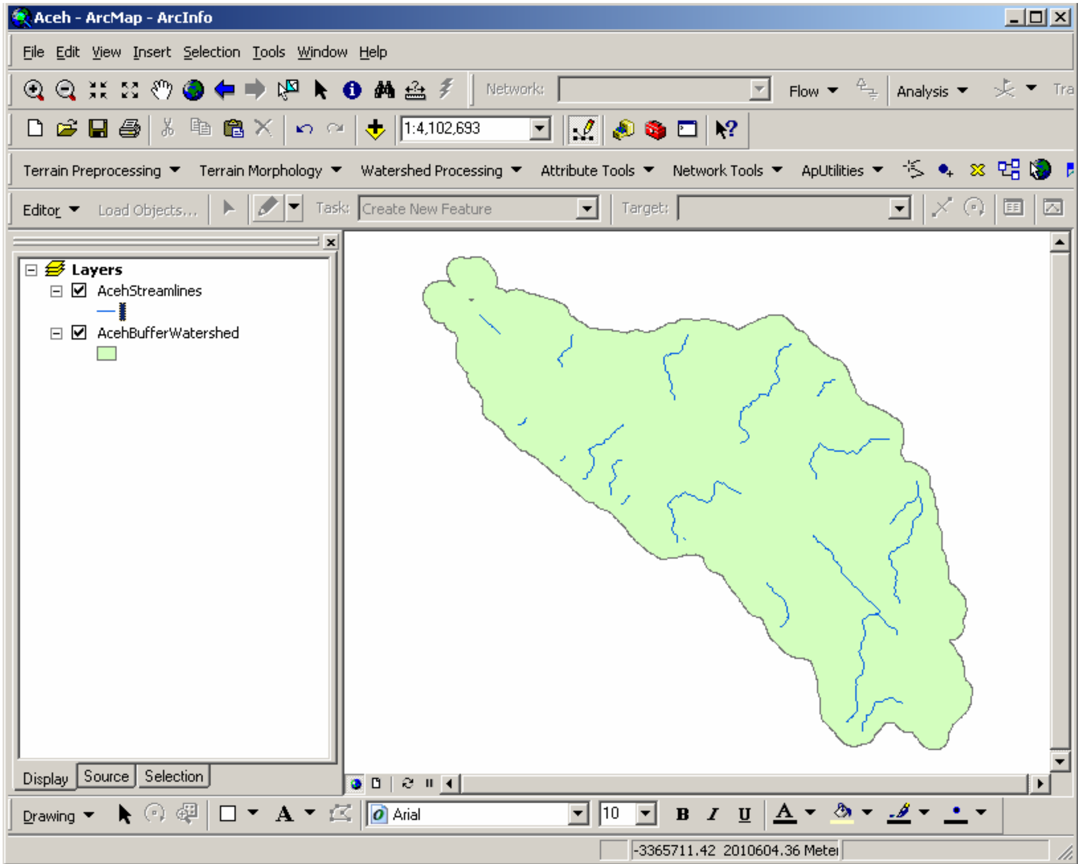
- Right click on the **Streamlines** layer and select **Data** / **Export Data**.
- Export the selected features to the **BaseMap** feature dataset and call the output **AcehStreamlines**. Click **OK** and **Yes** to add the exported data to the map.



- Right click on the **AcehStreamlines** layer and select Open Attribute Table.
- Add the following fields (**Options** / **Add Field**) if they are not present: **HydroID** (long int), **LengthDown** (double), **JunctionID** (long int). Close the attribute table.



- Remove the **Streamlines** layer from the map.



4. ArcHydro Raster Implementation

4.1 Introduction

The purpose of this exercise is to illustrate, step-by-step, how to use the major functionality available in the ArcHydro tools for Terrain Processing. This is a hands-on document focusing on how, not why. There is little discussion on implementation or internal operation of the tools. This document is targeted to an experienced water resources ArcGIS user who wants to learn how to use the tools. The online help provides more detail on the tools operation.

In this section, we will perform terrain analysis on a DEM of the Aceh Basin on Sumatra in Indonesia. The ArcHydro tools are used to derive several data sets that collectively describe the drainage patterns of the catchment. Raster analysis is performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. These data are then used to develop a vector representation of catchments and drainage lines from selected points. The utility of the ArcHydro tools is demonstrated by applying them to develop attributes that can be useful in hydrologic modeling. To accomplish these objectives, the user is exposed to important features and functionality of ArcHydro tools, both in raster and vector environments.

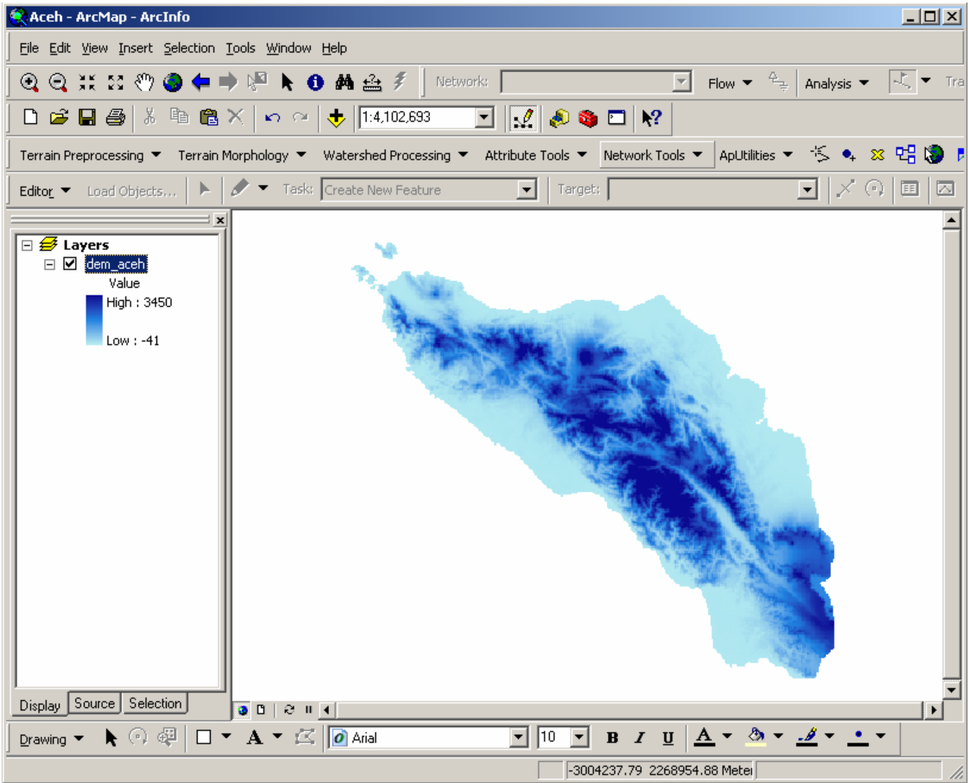
To carry out this exercise, you need to have a computer, which runs the **ArcInfo** version of ArcGIS. The data are provided in the accompanying directory:

\ArcHydro_Aceh\Exercises_Data\Participant

You will need the DEM raster **dem_aceh** (see last section) of the Aceh basin for this section.

4.2 Load the terrain data

- Open the **Aceh** ArcMap document and add the raster file **dem_aceh**.



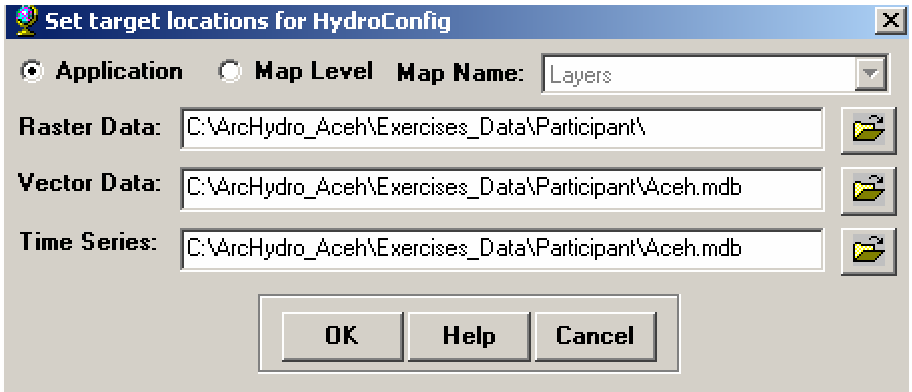
4.3 Terrain Preprocessing

Terrain Preprocessing uses the DEM to identify the surface drainage pattern. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation.

All the steps in the Terrain Preprocessing menu should be performed in sequential order, from top to bottom. DEM reconditioning and filling sinks might not be required, depending on the quality of the initial DEM. By doing the DEM reconditioning you can be sure any point on the stream network will represent a cell (stream cell) for which you can process and compute attributes.

Be aware, some of the terrain processes may take some time to finish. Processes like Filling Sinks took about **50 minutes** to process on one of our computers, so please be patient!

The existing data to be used in an ArcHydro project can be stored in any geodatabase and loaded in the map. All vector data created with the ArcHydro tools will be stored in a new geodatabase that has the same name as the ArcMap document (unless pointed to an existing geodatabase) and in the same directory where the project has been saved. By default, the new raster data are stored in a subdirectory with the same name as the dataset or Data Frame in the ArcMap document (called **Layers** by default and under the directory where the project is stored). The location of the vector, raster, and time series data can be explicitly specified by going to **ApUtilities / Set Target Locations** in the **ArcHydro** tools.



4.3.1 DEM Reconditioning

This function modifies a DEM by imposing linear features onto it (burning/fencing).

The process includes:

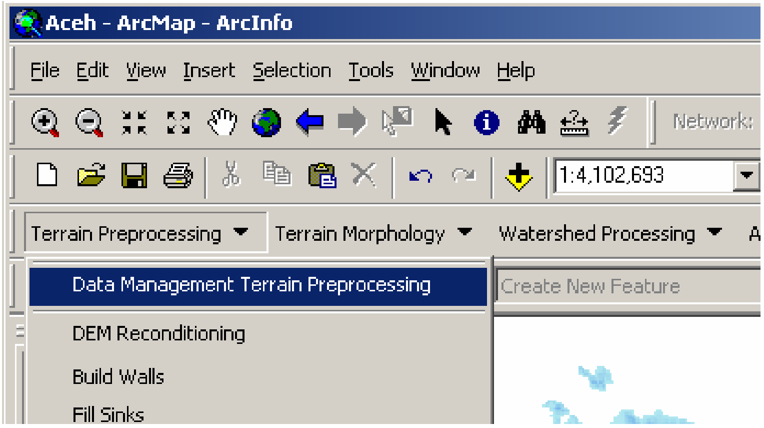
- Taking a stream network and a DEM
- Making a grid of the streams
- Dropping the stream DEM cells by an arbitrary elevation increment

Produces "burned in" DEM streams = mapped streams. It is an implementation of the AGREE method developed at the University of Texas at Austin in 1997. For a full reference to the procedure refer to the web link

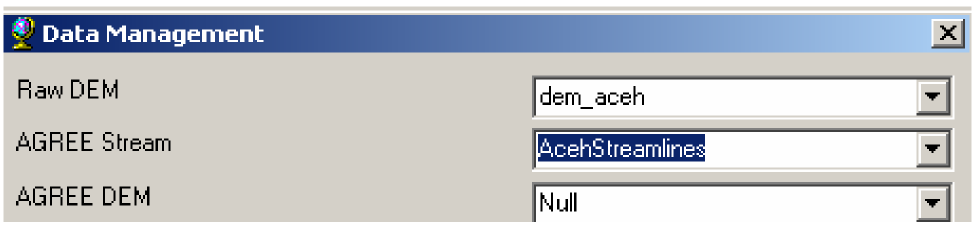
http://www.ce.utexas.edu/prof/maidment/GISHYDRO/ferdi/research/agree/agree.html.

The function needs as input a raw dem and a linear feature class (like the river network) that both have to be present in the map document. **We do NOT have a sufficient linear feature class necessary so we will bypass the process**. However, the steps to the process are still outlined below for you to reference if you do have the necessary input for future projects.

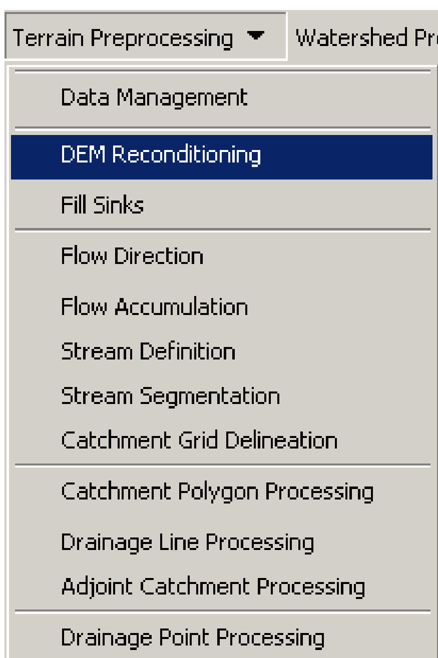
- Select **Terrain Preprocessing** / **Data Management Terrain Preprocessing** in the **ArcHydro** tools.



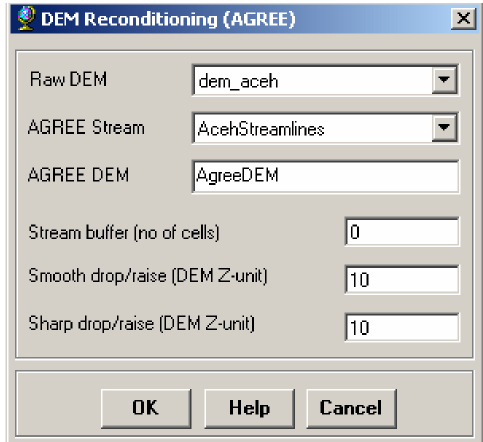
- Select **dem_aceh** for *Raw DEM* and **AcehStreamlines** as *AGREE Stream*.



- Select **Terrain Preprocessing / DEM Reconditioning** in the **ArcHydro** tools.



- Select the appropriate dem and linear feature. The output is a reconditioned **Agree DEM** (default name AgreeDEM).

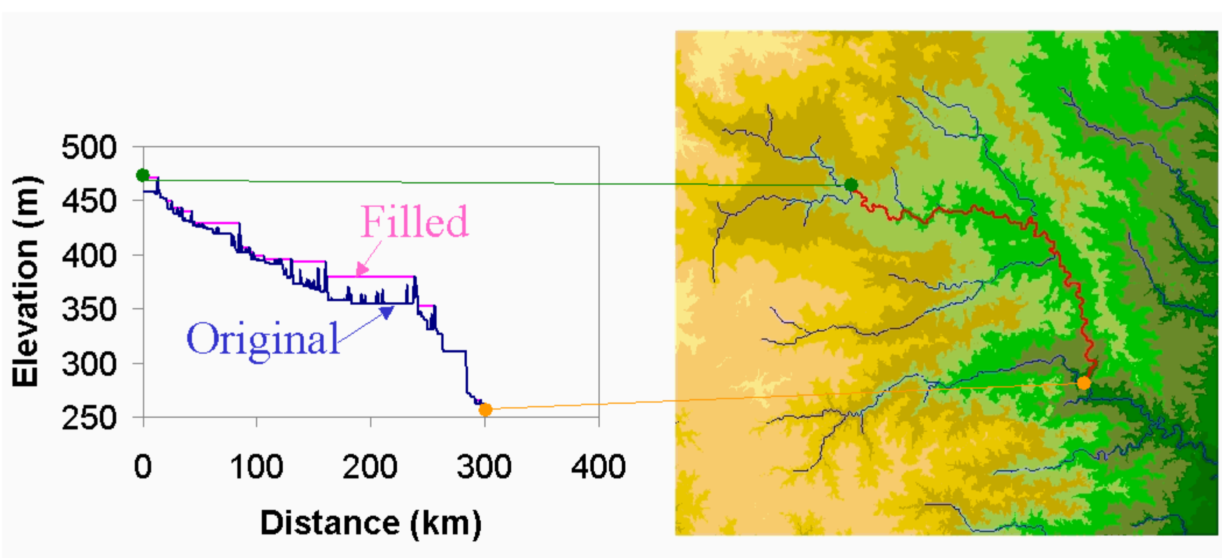


This process takes about **5 minutes**!

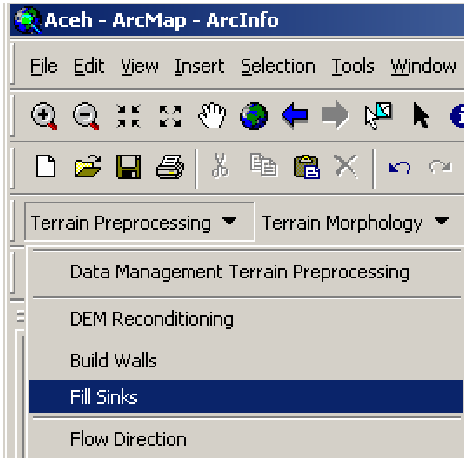
After the process is completed you can use **ArcCatalog** to view the files. Go to the work folder and see that there is a folder named **Layers**, this folder will contain the grids created in the delineation process. Also a geodatabase with the name of the map, in this case **ArcHydroRaster.mdb**, is automatically created and will store the vector results.

4.3.2 Fill Sinks

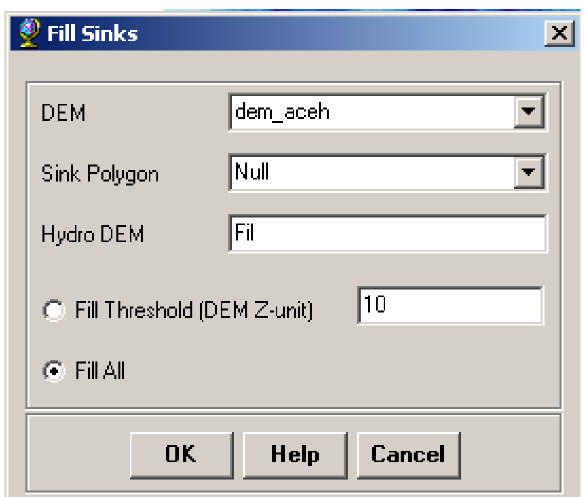
*DEM creation results in artificial pits (sinks) in the landscape. A pit is a set of one or more cells which has no downstream cells around it. Unless these pits are filled they become sinks and isolate portions of the watershed. The **Fill Sinks** function modifies the elevation value to eliminate these problems.*



- Select **Terrain Preprocessing / Fill Sinks**.



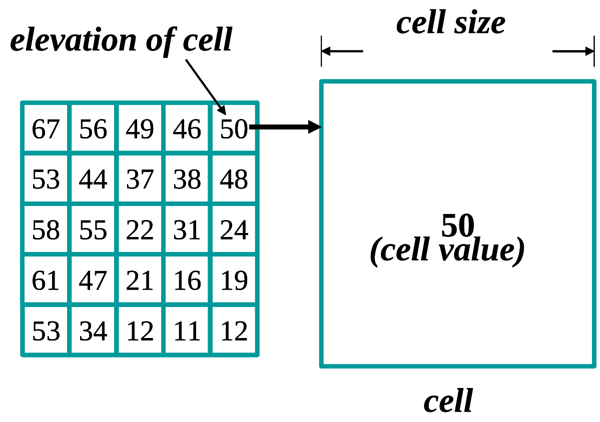
- Confirm that the input for *DEM* is **dem_aceh** and leave the remaining fields as their default settings. The output is the Hydro DEM layer, named by default **Fil**. This default name can be overwritten. Click **OK**.



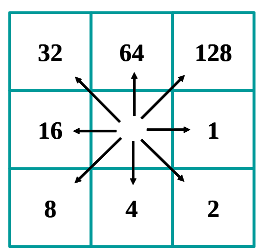
- Upon successful completion of the process, the **Fil** layer is added to the map (this process takes approximately **50 minutes**).

4.3.3 Flow Direction

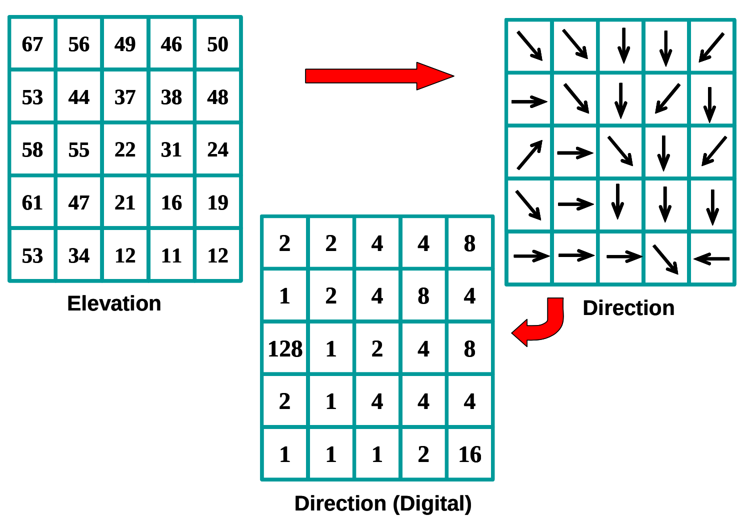
Digital Elevation Models (DEM) are made up of cells of a particular dimension with an elevation value assigned to each cell.



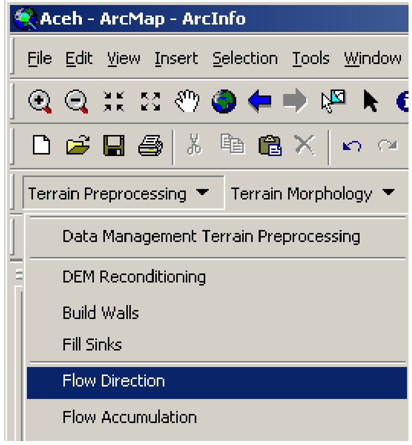
Using the **Eight Direction Pour Point Model,** water is assumed to be constrained to flow from one cell to one of the 8 adjacent cells. Each cell is assigned a value as shown based on the steepest path rule.



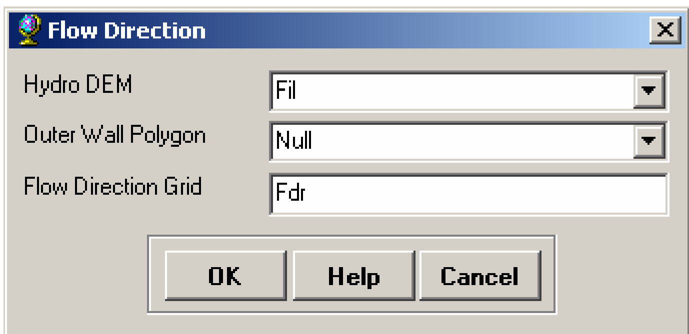
Using the Eight Direction Pour Point Model a **Flow Direction Grid** can be constructed from the DEM.



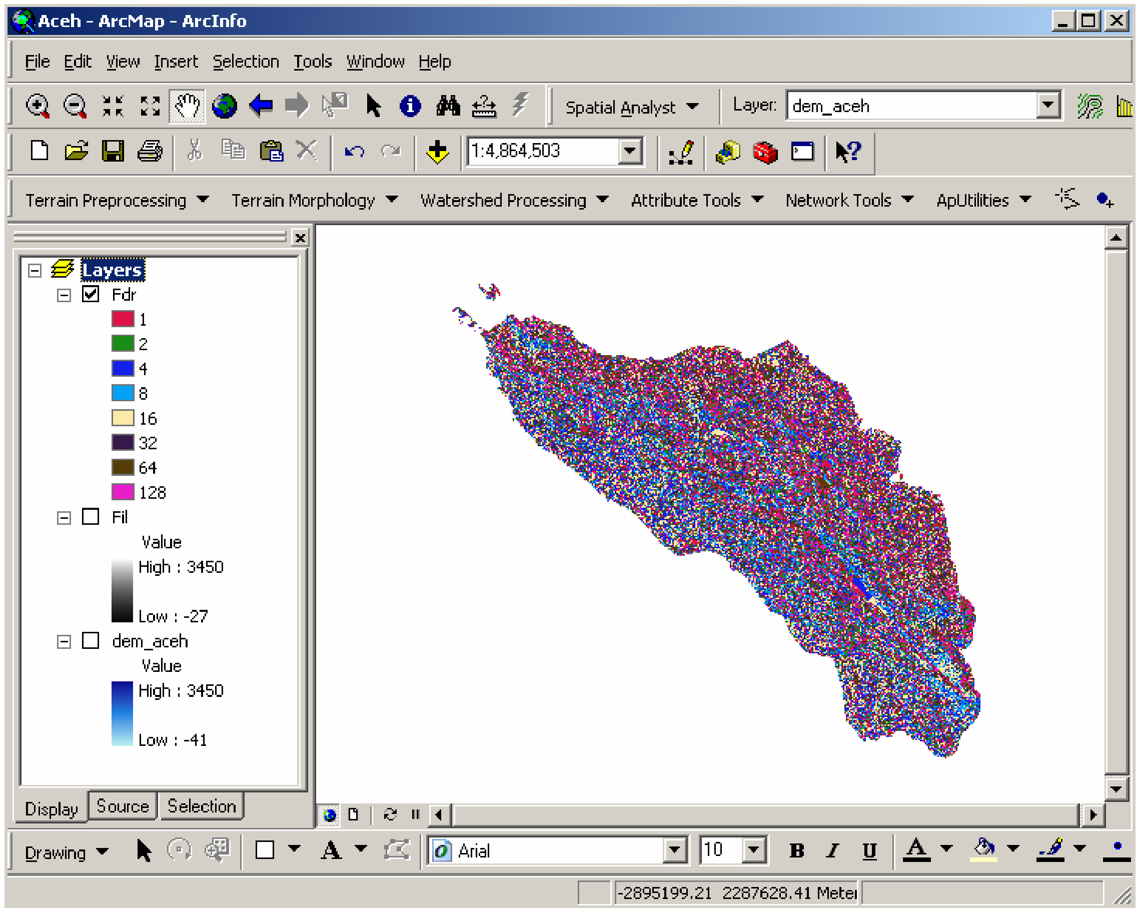
- Select **Terrain Preprocessing / Flow Direction**. This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.



- Confirm that the input for *Hydro DEM* is **Fil**. The *Flow Direction Grid* is named **Fdr** by default. This default name can be overwritten. Click **OK**.



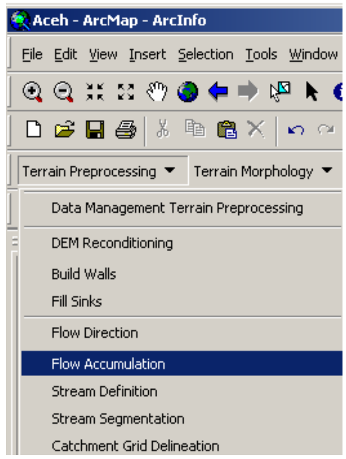
- The flow direction grid **Fdr** is added to the map upon successful completion of the process (approximately **5 minutes** to complete).



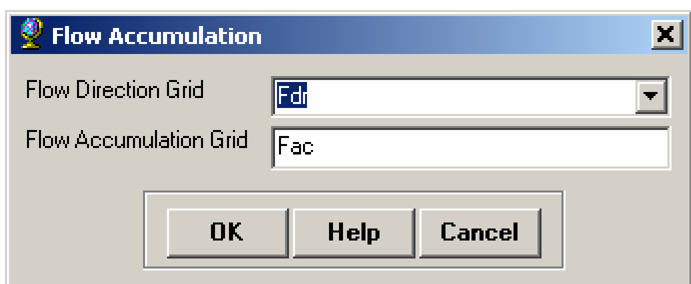
4.3.4 Flow Accumulation

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

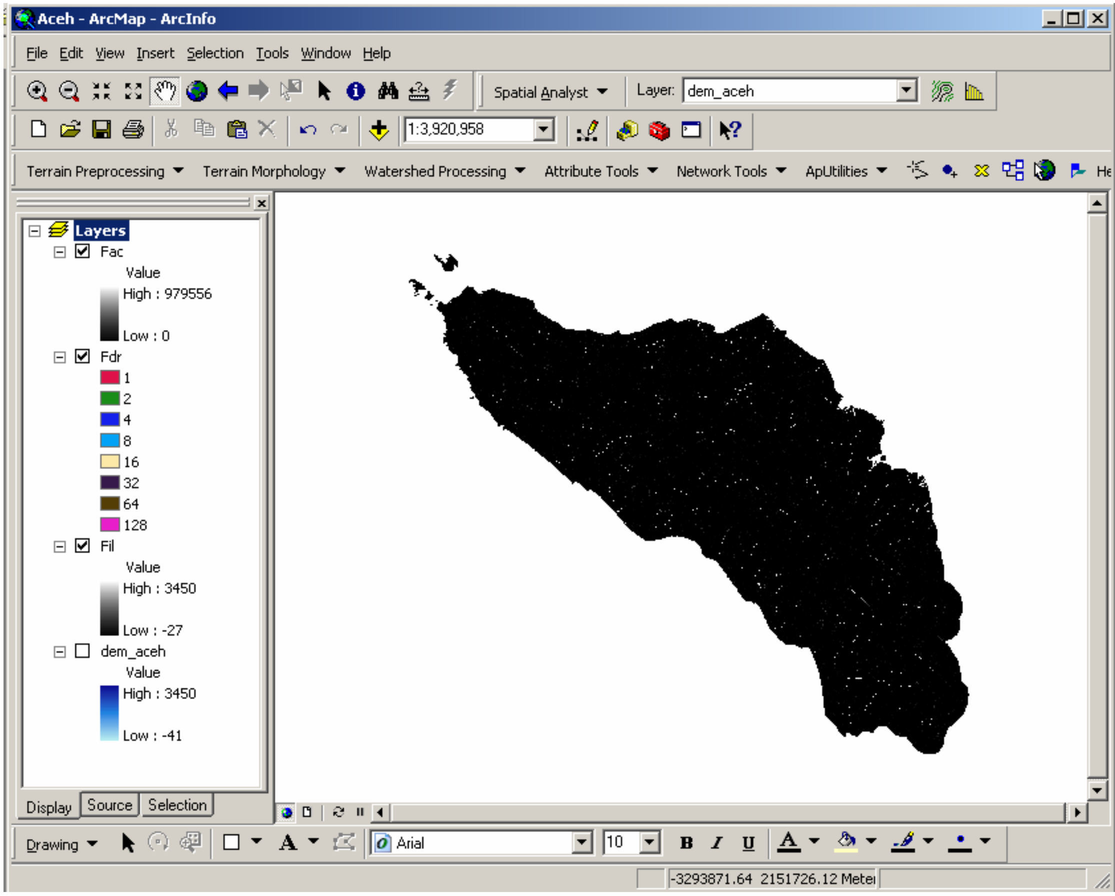
- Select **Terrain Preprocessing / Flow Accumulation**.



- Confirm that the input of the *Flow Direction Grid* is **Fdr**. The output is the *Flow Accumulation Grid* having a default name of **Fac** that can be overwritten. Click **OK**.



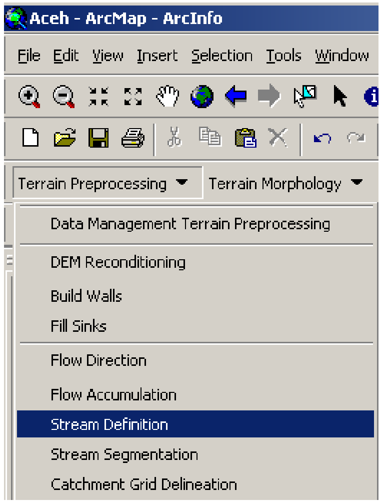
- The flow accumulation grid **Fac** is added to the map upon successful completion of the process (approximately **20 minutes** to complete).



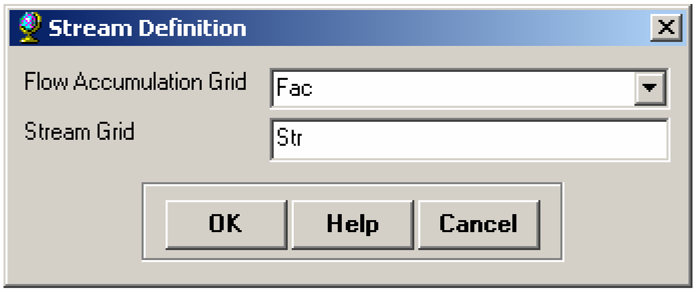
4.3.5 Stream Definition

This function computes a stream grid which contains a value of "1" for all the cells in the input flow accumulation grid that have a value greater than the given threshold. All other cells in the Stream Grid contain no data.

- Select **Terrain Preprocessing / Stream Definition.**

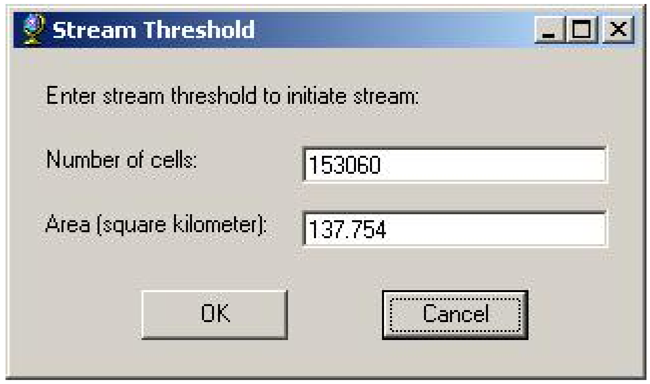


- Confirm that the input for the *Flow Accumulation Grid* is **Fac**. The output is the *Stream Grid* having a default name of **Str** that can be overwritten. Click **OK**.

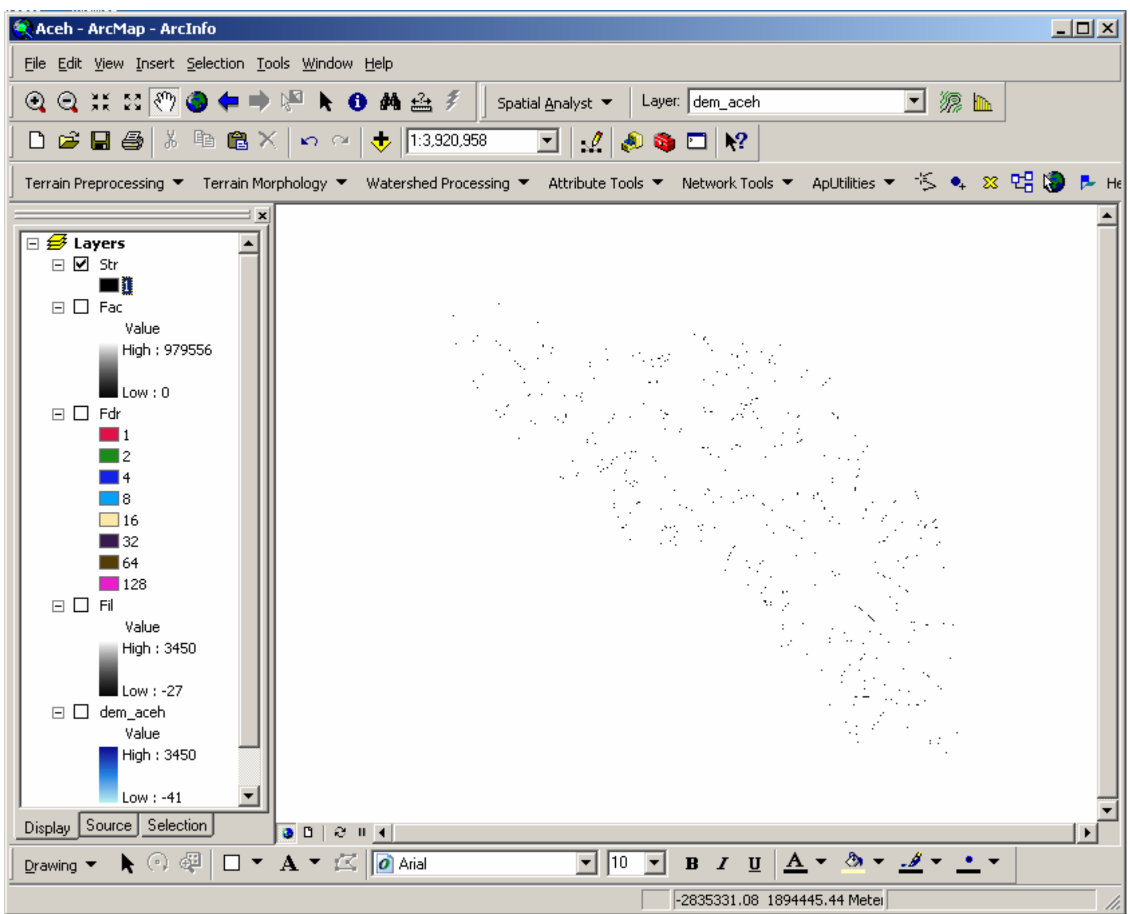


A default value is displayed for the river threshold. This value represents **1%** of the maximum flow accumulation: it is the recommended threshold for stream determination. However, any other value of threshold can be selected. **A smaller threshold will result in a denser stream network and usually in a greater number of delineated catchments**.

*Note: For the control points we will be using later in the exercise, an area of **2 square kilometers** will need to be used as the threshold*



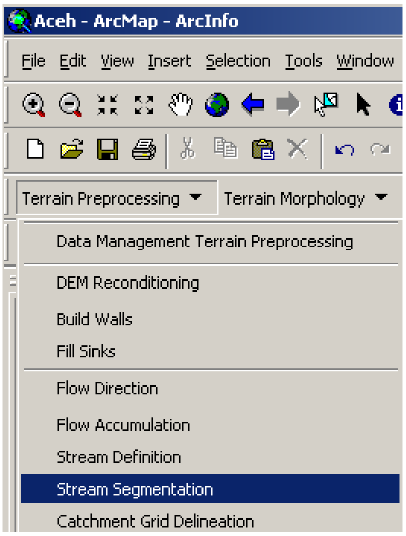
- Click **OK**. Upon successful completion of the process, the stream grid **Str** is added to the map (**1-2 minutes**).



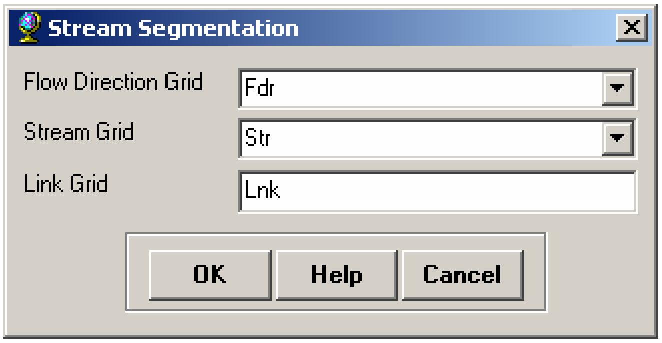
4.3.6 Stream Segmentation

This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment.

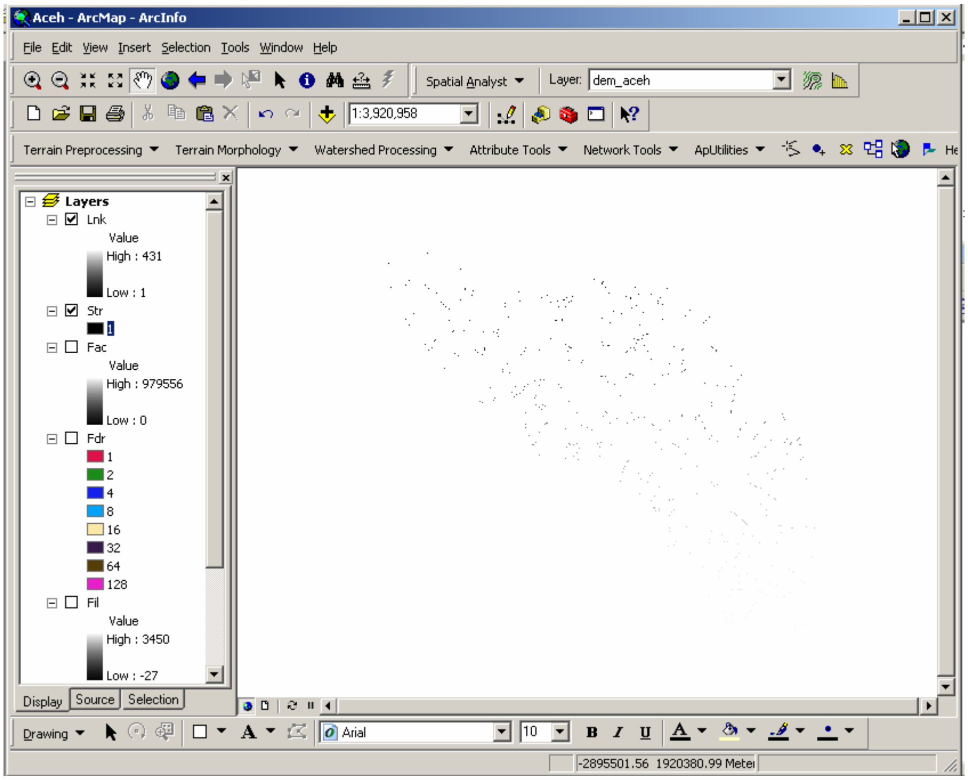
- Select **Terrain Preprocessing / Stream Segmentation.**



- Confirm that **Fdr** and **Str** are the inputs for the *Flow Direction Grid* and the *Stream Grid*, respectively. The output is the *Link Grid* with the default name **Lnk** that can be overwritten. Click **OK**.



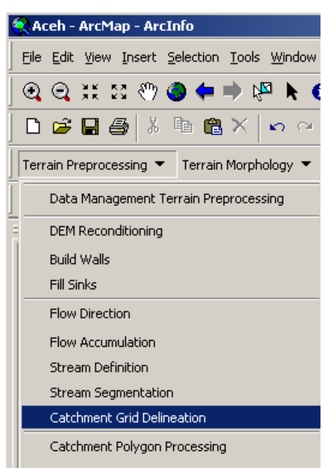
- Upon successful completion of the process, the link grid **Lnk** is added to the map (**1-2 minutes**).



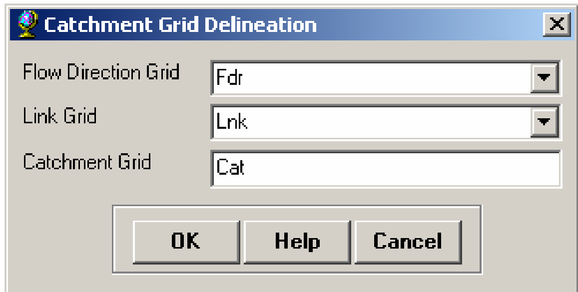
4.3.7 Catchment Grid Delineation

This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid.

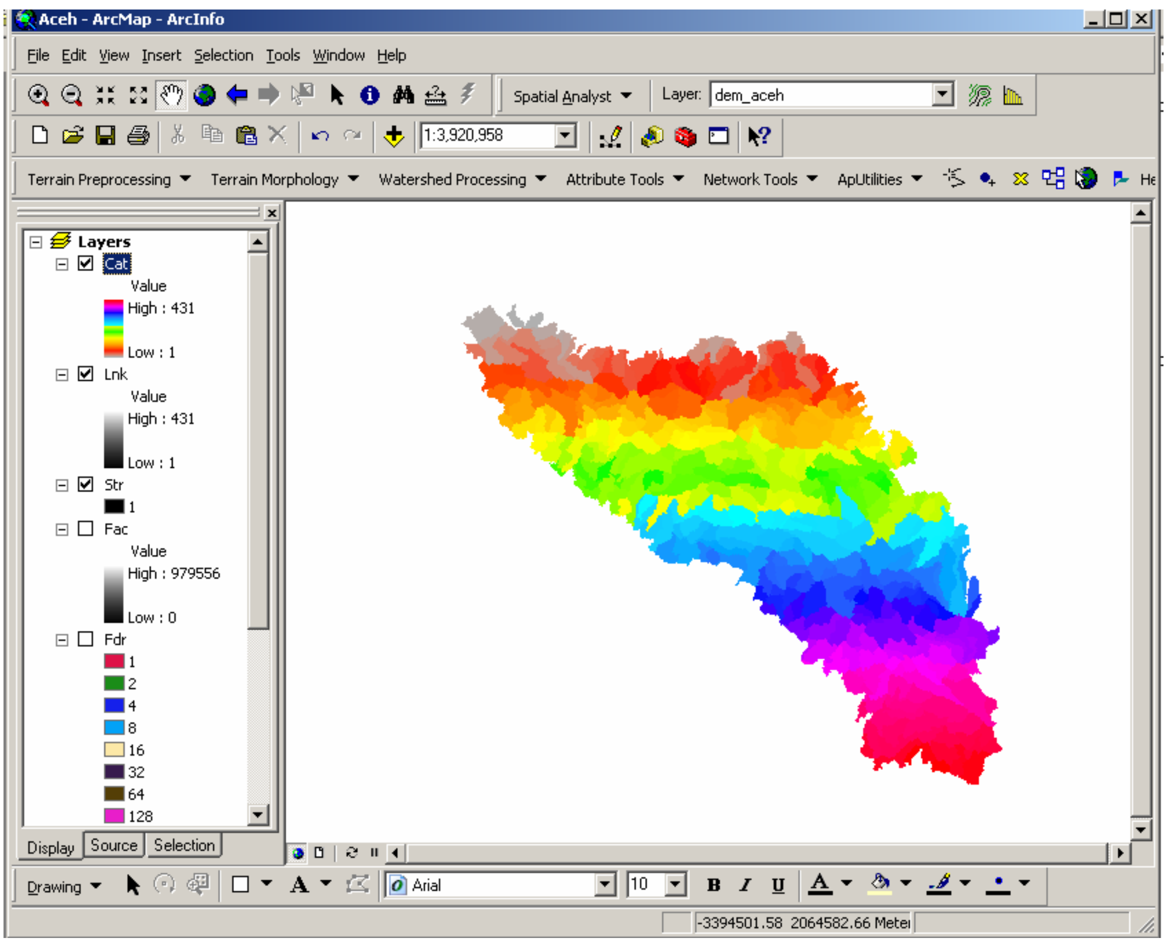
- Select **Terrain Preprocessing / Catchment Grid Delineation**.



- Confirm that the input to the *Flow Direction Grid* and *Link Grid* are **Fdr** and **Lnk,** respectively. The output is the *Catchment Grid* layer with the default name **Cat** that can be overwritten by the user. Click **OK**.



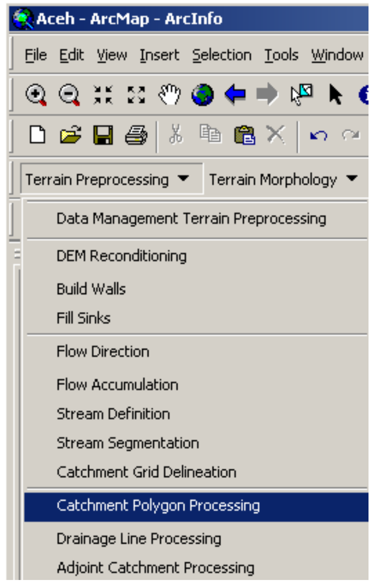
- Upon successful completion of the process, the Catchment grid **Cat** is added to the map (approximately **5-10 minutes** to complete).



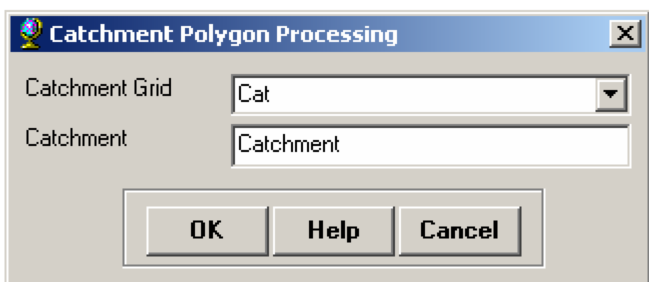
4.3.8 Catchment Polygon Processing

This function converts a catchment grid into a catchment polygon feature.

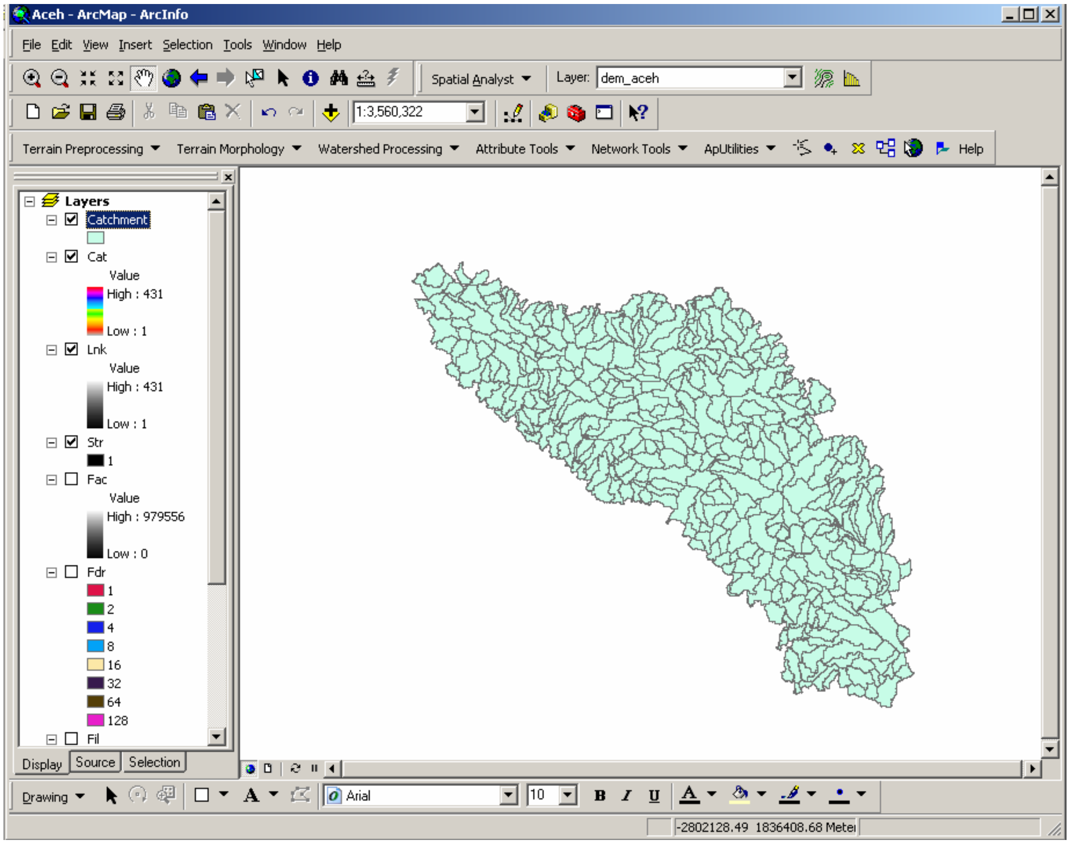
- Select **Terrain Preprocessing / Catchment Polygon Processing**.



- Confirm that the input to the *Catchment Grid* is **Cat**. The output is the *Catchment* polygon feature class, having the default name **Catchment**. Click **OK**.



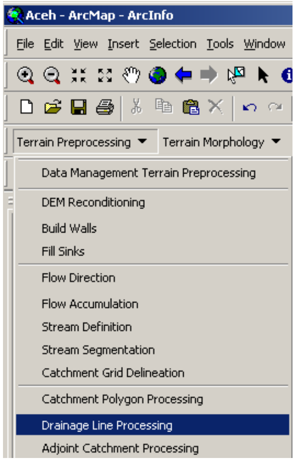
- Upon successful completion of the process, the polygon feature class **Catchment** is added to the map (approximately **5 minutes** to complete).



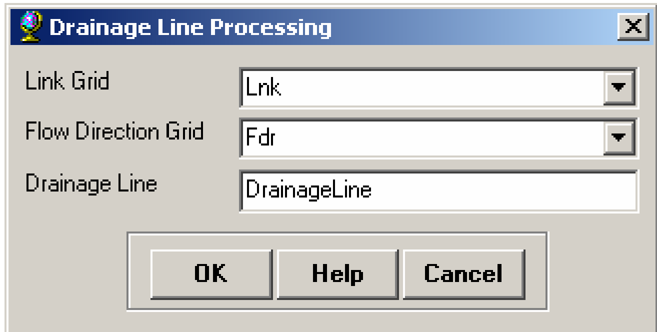
4.3.9 Drainage Line Processing

This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

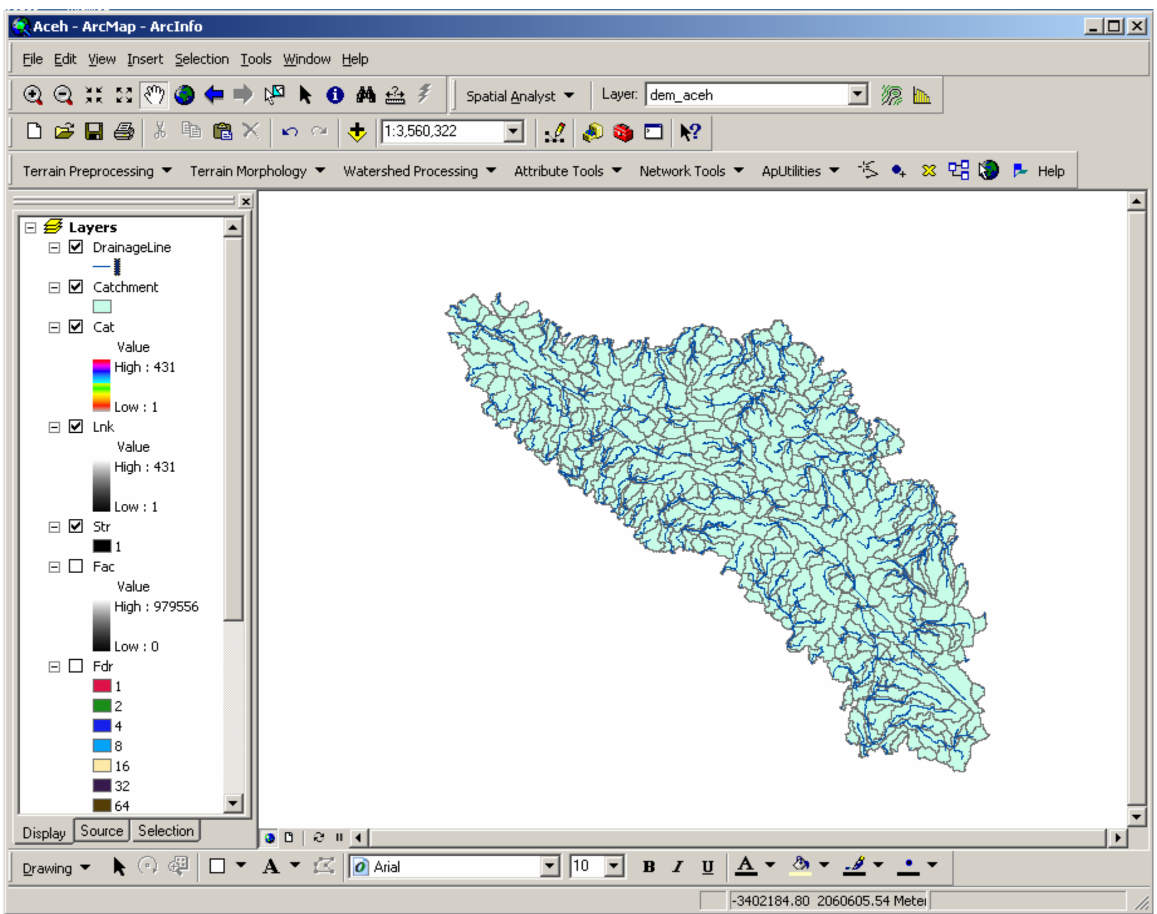
- Select **Terrain Preprocessing / Drainage Line Processing**.



- Confirm that the input to *Link Grid* is **Lnk** and to *Flow Direction Grid* is **Fdr**. The output *Drainage Line* has the default name **DrainageLine**. Click **OK**.



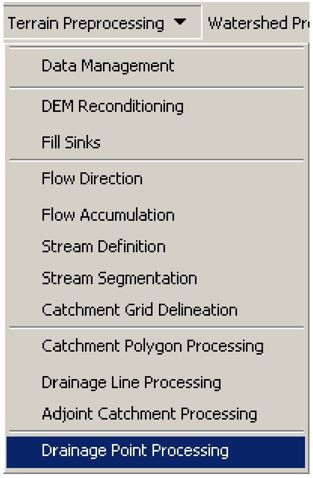
- Upon successful completion of the process, the linear feature class **DrainageLine** is added to the map (approximately **5-10 minutes** to complete).



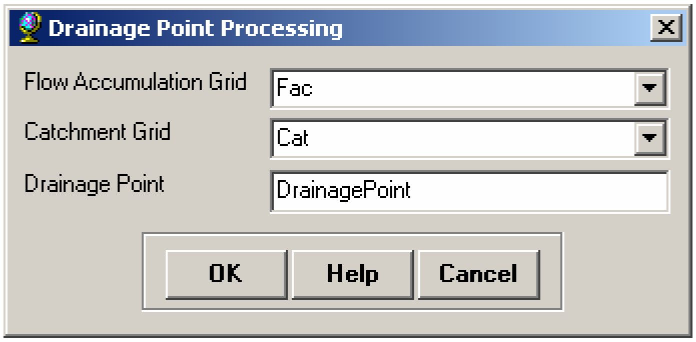
4.3.10 Drainage Point Processing

This function generates the drainage points associated with the catchments.

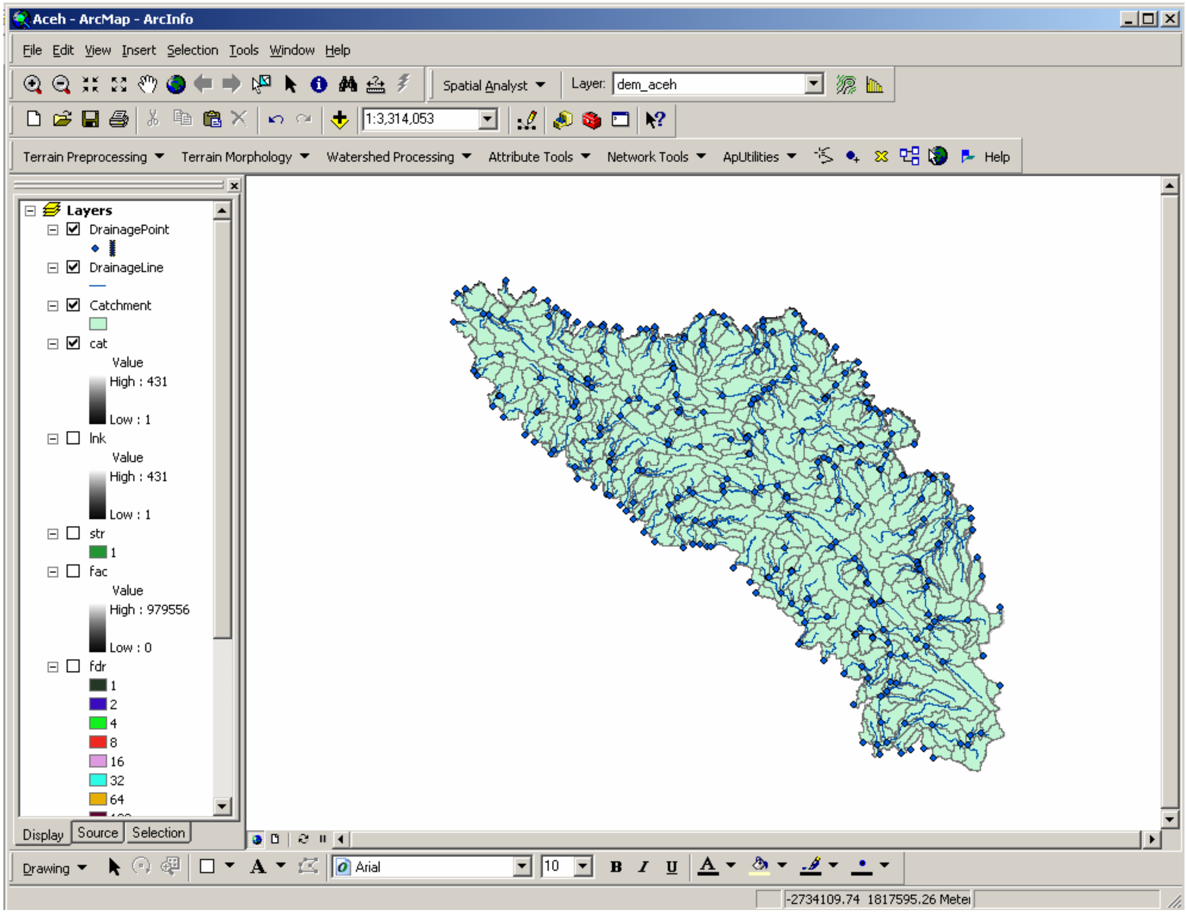
- Select **Terrain Preprocessing / Drainage Point Processing**.



- Confirm that the input to *Drainage Line* is **DrainageLine** and the input to *Catchment* is **Catchment**. The output is *Drainage Point*, having the default name **DrainagePoint**. Click **OK**.



* Upon successful completion of the process, the point feature class **DrainagePoint** is added to the map (approximately **25 minutes** to complete).



5. WRAPHydro Process

5.1 Introduction

In this section, we apply the WRAPHydro process to the Aceh River basin. The main phases involved in this process are **Preprocessing** and **Watershed Parameterization**.

After the base data are obtained, the initial analysis area is defined and some preprocessing is performed, which is required to calculate the final watershed parameters. The preprocessing basically deals with defining the basin boundary to set the analysis extent for any further processing. The **ArcHydro** and **WRAPHydro** tools are then used to calculate watershed parameters for the Aceh basin.

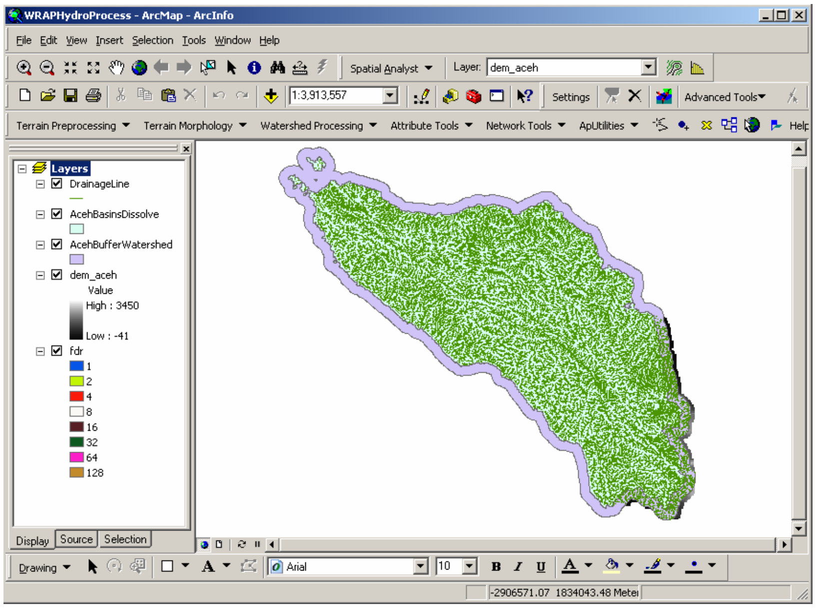
To complete this section, you need to have a computer system running ArcGIS with an ArcInfo license and the Spatial Analyst extension active. The ArcHydro tools and WRAPHydro tools must be installed on the computer. The WRAPHydro tools may be downloaded from Dr. David Maidment's Student Homepages website at

http://www.ce.utexas.edu/prof/maidment/grad/whiteaker/hydrotools.html

5.2 Preprocessing

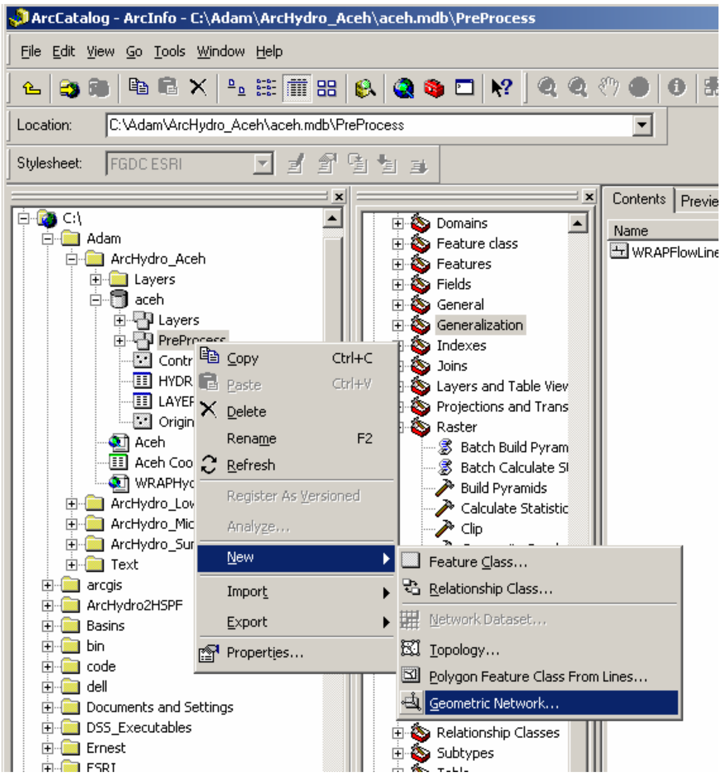
5.2.1 Select the polygon corresponding to the Aceh basin

- Open ArcMap. Save a new document as **WRAPHydroProcess.mxd**.
- Add the **AcehBasinsDissolve**, **DrainageLine**, and the **AcehBufferWatershed** feature classes to the map.
- Add the **dem_Aceh** and the Flow Direction (**fdr**) rasters to the map.



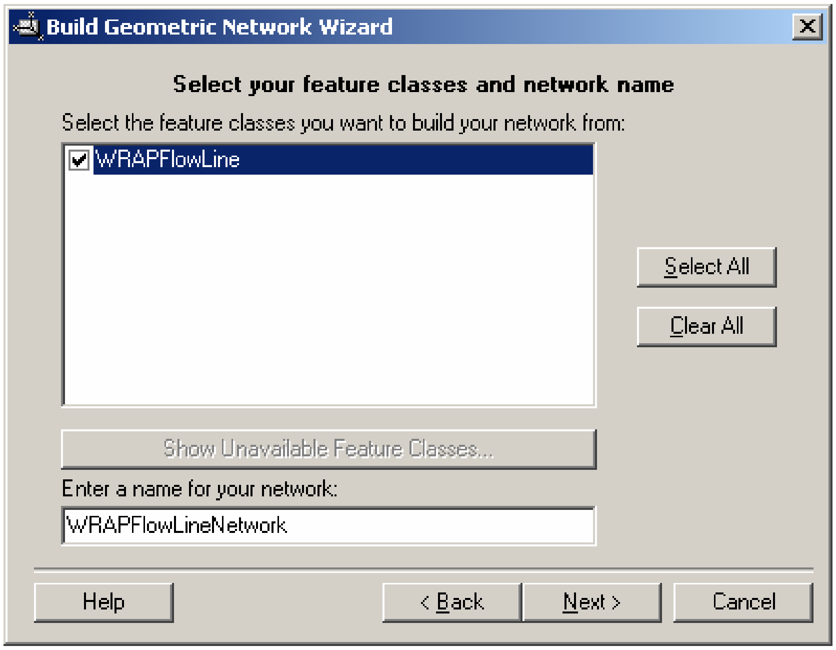
5.2.2 Build a network with Flowlines as a complex edge

- **Save** the ArcMap document. **Close** ArcMap and **open** ArcCatalog.
- Right click on the Aceh.mdb Geodatabase and select **New / Feature Dataset.**
- Name the new feature dataset **PreProcess.**
- **Import** the projection parameters from the **BaseMap** feature dataset.
- **Export** the **DrainageLine** feature class from the **Layers** feature dataset to the **PreProcess** feature dataset and name it **WRAPFlowLine.**
- Right click on the **PreProcess** feature dataset inside the Aceh Geodatabase.
- Click **New / Geometric Network**. The **Build Geometric Network Wizard** opens.

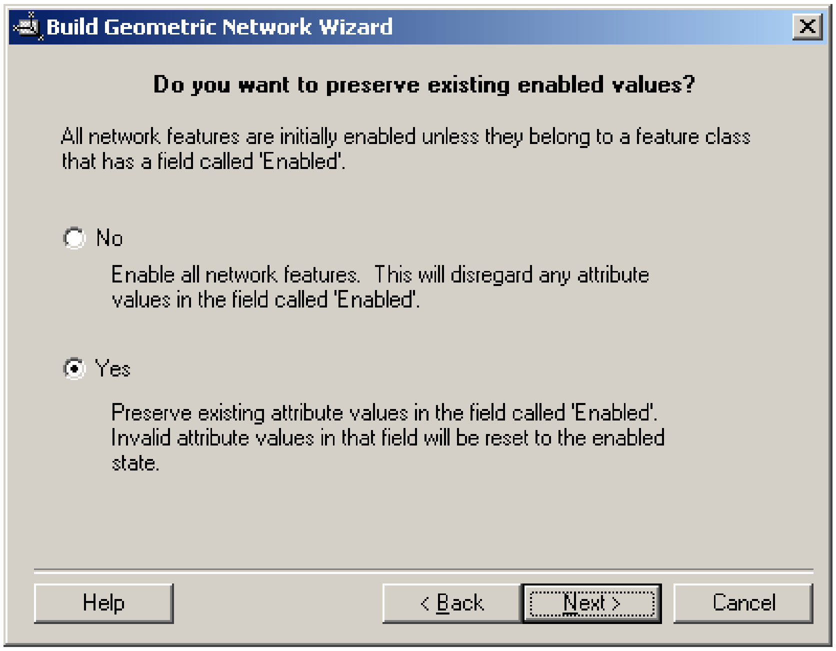


- Click **Next** to skip the first screen in the wizard.
- Make sure '*Build a geometric network from existing features*' is selected and click **Next**.

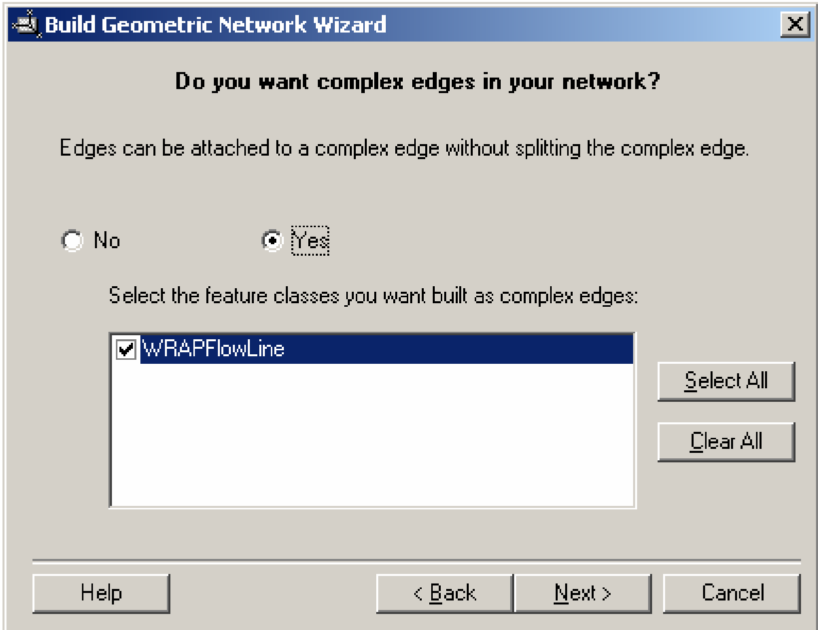
- Choose the **WRAPFlowline** as the feature class to create the network from. Call the network **WRAPFlowLineNetwork** and click **Next**.



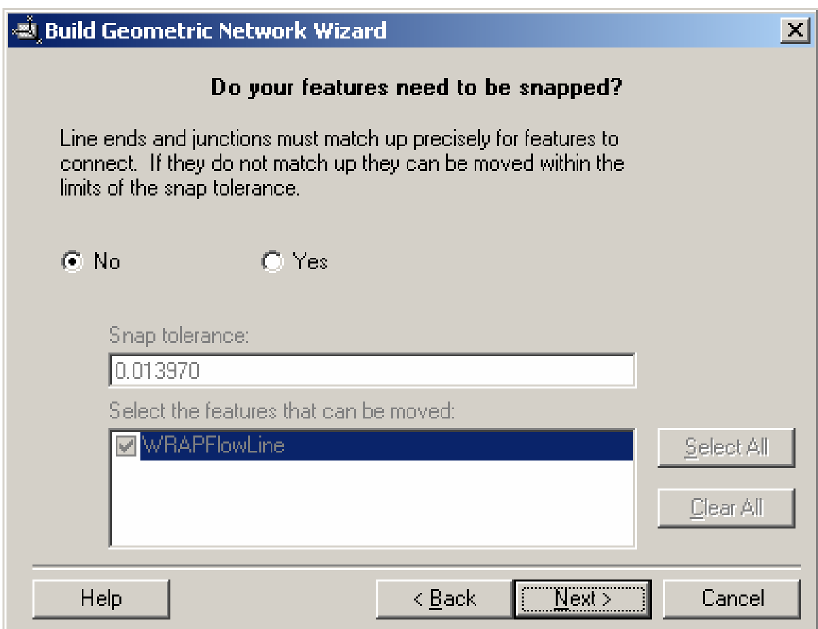
- Choose **Yes** to preserve the existing enabled values (if this window appears) and click **Next**.



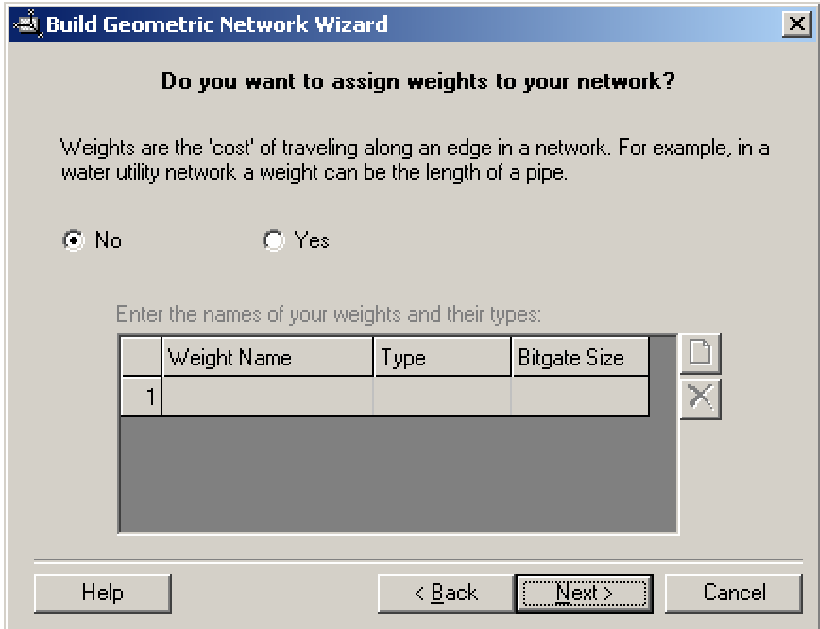
- Choose **Yes** to build the geometric network with **WRAPFlowLine** as a complex edge and click **Next**.



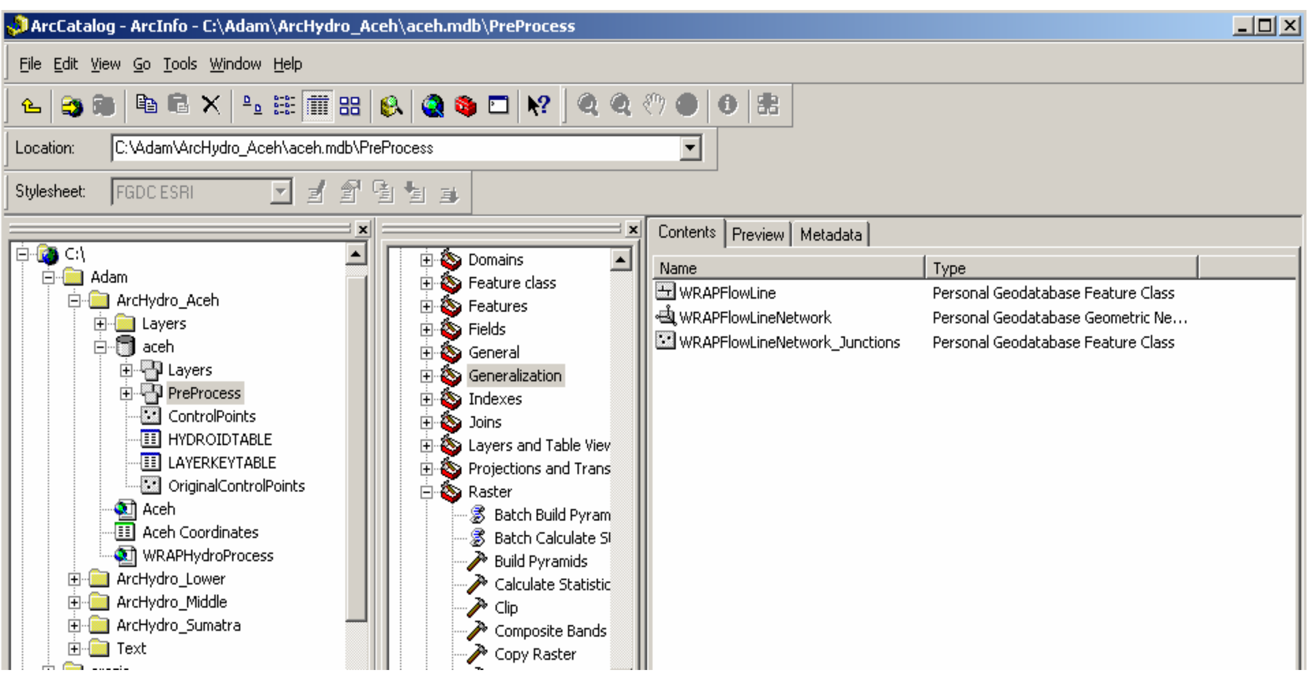
- Choose **No** as the features do not need to be snapped. Click **Next**.



- Choose **No** to not assign weights to the network. Click **Next**.



- Click **Finish** to create the geometric network. When the process has completed, you will see a **WRAPFlowLineNetwork** icon and a **WRAPFlowLineNetwork_Junctions** icon in the **PreProcess** feature dataset.



5.2.3 Assign HydroIDs to the WRAPFlowLine edges.

Basins are identified by a ten digit integer **HydroID**. The first digit specifies the Administrative Directorate, defined for the purposes of this exercise as the number **1** for the Aceh Directorate. The next two digits are allocated for the hydrological subregion, or basin. The number **01** is assigned to the Aceh basin (It is assumed here that all basins will have no more than 99 basins). The next two digits represent the type of geographic information being managed (feature class). The number 01 is assigned for control points, 02 for flow lines, 03 for water bodies, 04 for watersheds, and so on. The last five digits describe the number of the element, so each feature class may have 99,999 elements.

Table 4.1. Regional HydroID Assignment for every feature class in the Geodatabase

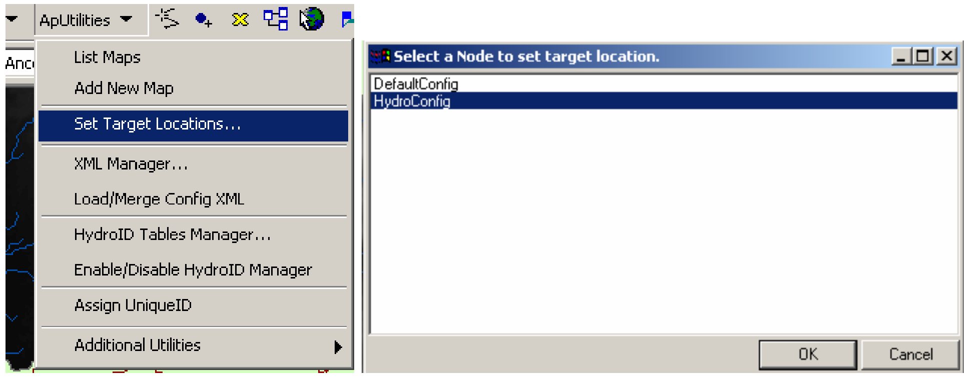
- 1st digit (**blue box**): Hydro-Administrative Region
- 2nd two digits (**yellow boxes**): Sub Region or Basin
- 3rd & 4th digits (**red boxes**): Feature Class
  - Control Point: 01
  - HydroEdge: 02
  - WaterBody: 03
  - Watershed: 04
  - And so on
- 5th – 9th digits (**green boxes**): Feature Number (1 - 99 999)

These WRAPFlowLines lie within the Aceh basin, so all HydroIDs for WRAPFlowLines will begin with the number 01 to indicate the **Aceh basin**. After the regional identifier, the number 02 indicates that these features are **flow lines**. So, each WRAPFlowLine HydroID will be prefixed by _0102, and the last five digits will describe the number for every stream.

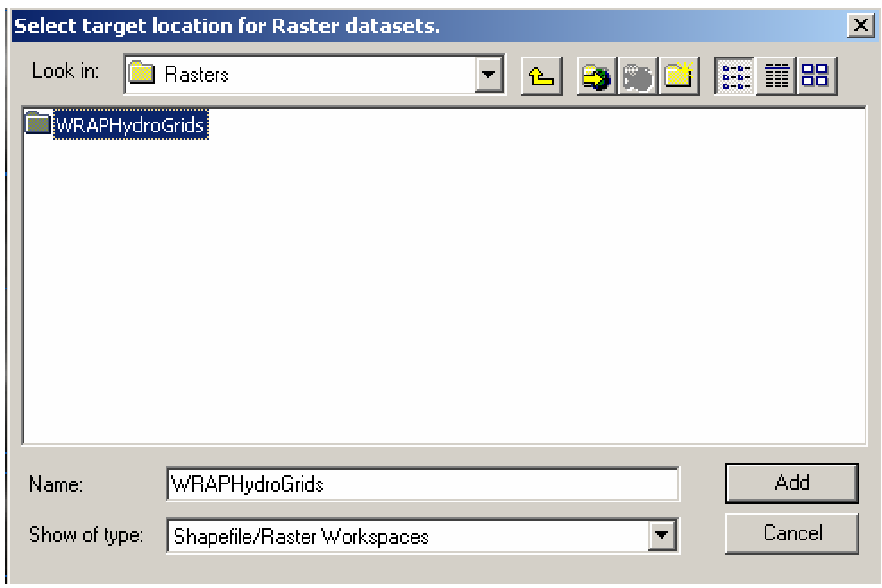
5.2.3.1 Set Target Locations for HydroIDs

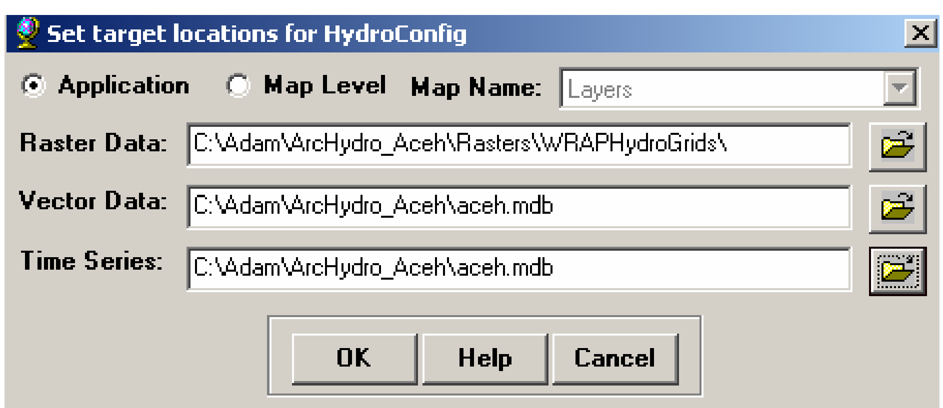
- Create a new folder called **WRAPHydroGrids** in the **Raster** folder.
- Close **ArcCatalog** and open the **WRAPHydroProcess** ArcMap document.
- Add the **WRAPFlowLines** layer to the map and remove **DrainageLines**.

- Click the **Set Target Locations** in the **ApUtilities.** Then select **HydroConfig** from the next box.



- Select **WRAPHydroGrids** as the target for **Rasters** and **Aceh.mdb** as the target for **Vectors** and **Time Series**.



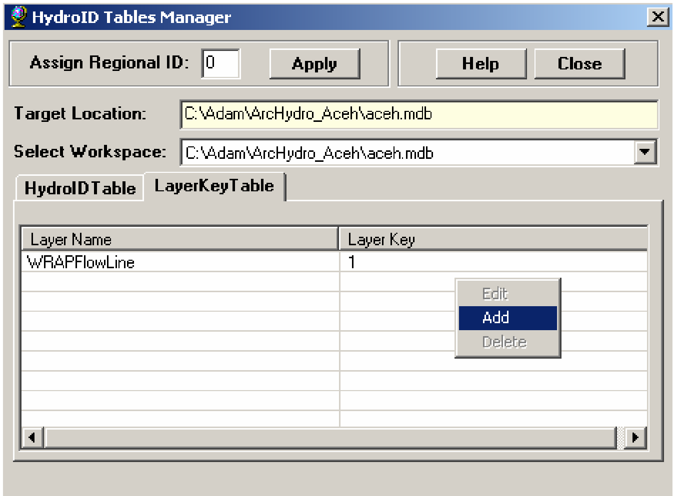


5.2.3.2 Set Starting HydroIDs for WRAPFlowLines

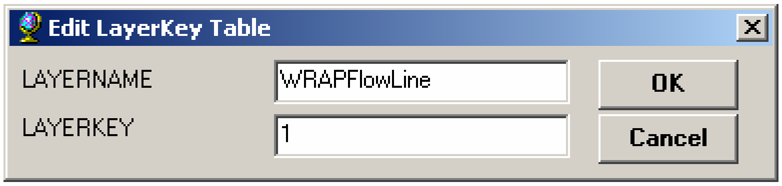
- Click the Editor Toolbar and click **Start Editing**.

*Hint: If the editor toolbar is not visible, add it by clicking **View / Toolbars / Editor**.*

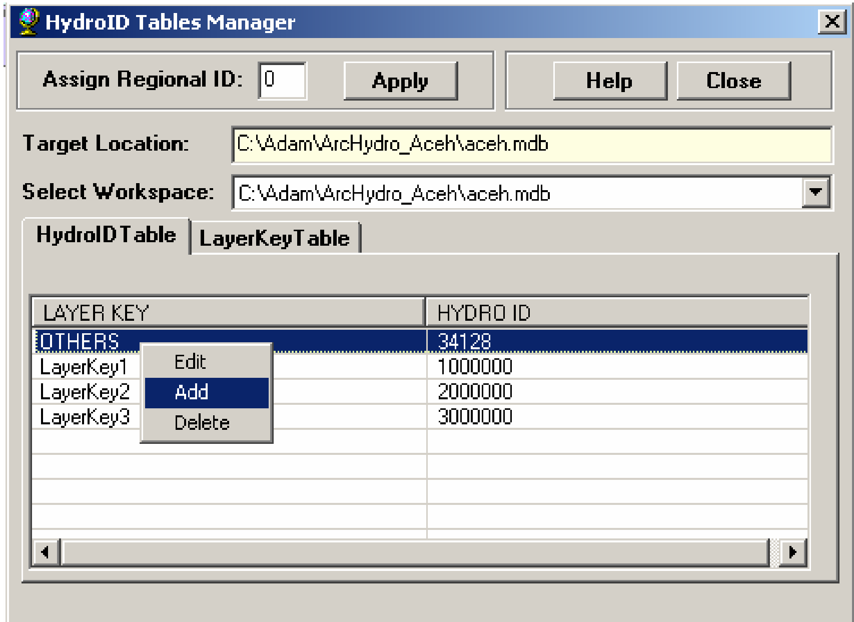
- Go to the **HydroID Tables Manager** in the **ApUtilities** menu of the **ArcHydro** toolbar. Click the **LayerKey Table** tab.
- Right click in the first blank under the words *Layer Name* and click **Add**.



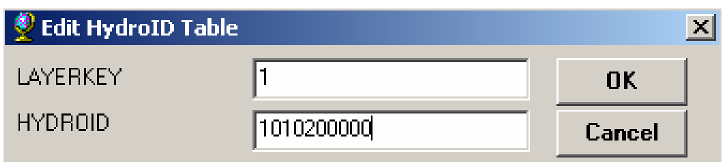
- Type **WRAPFlowLine** as the layer name and **1** as the layer key. Click **OK**.

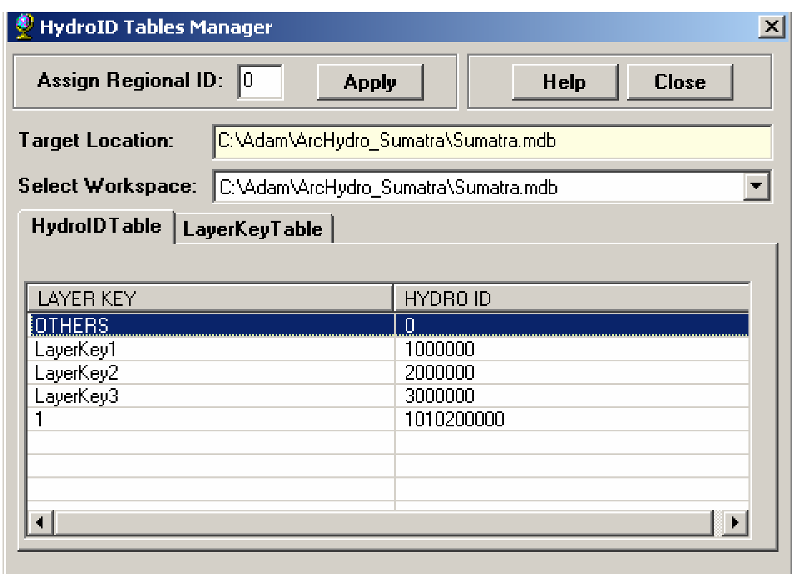


- Click on the **HydroID Table tab** to provide a **HydroID** starting point for the **WRAPFlowLine** layer key. To establish this key, right click on the word "OTHERS" under Layer Key and click **Add**.



- Type "**1**" as the **Layer Key** and **1010200000** as the **HydroID**. Thus, the first HydroID assigned to a WRAPFlowLine will be 1010200001; the second will be 1010200002, and so on. Click **OK**.

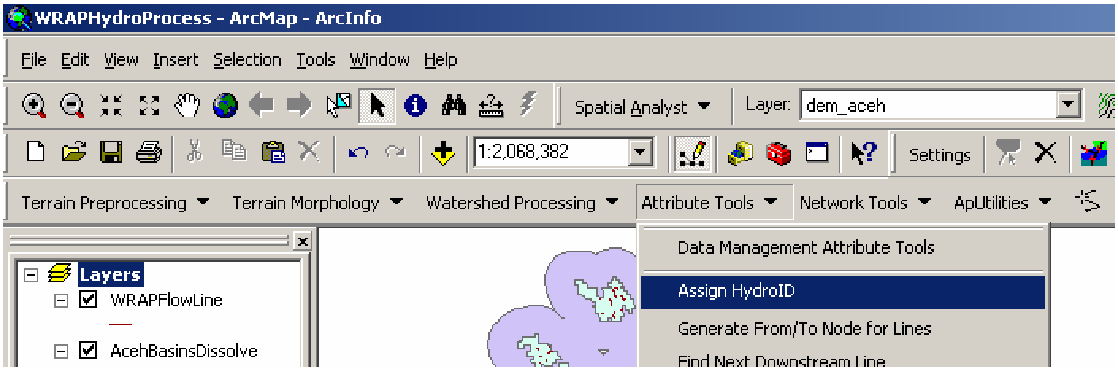




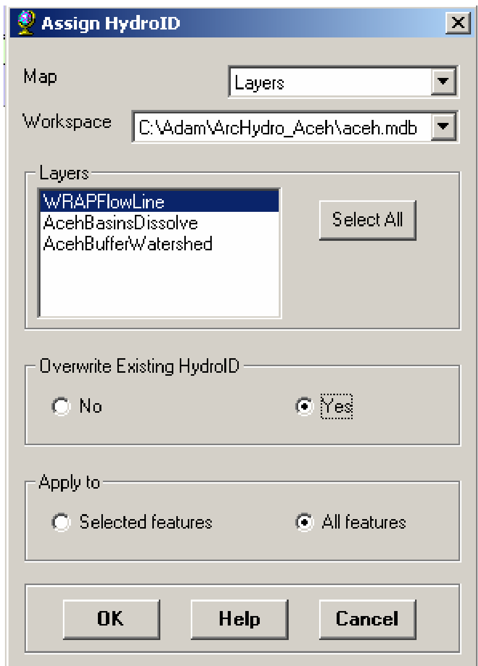
- Click **Close** to close the **HydroID Tables Manager**. Stop the editing process.

5.2.3.3 Assign HydroIDs to WRAPFlowLines

- In the **Attribute Tools** menu of the **ArcHydro** toolbar, click **Assign HydroID**.



- Highlight the **WRAPFlowline** feature class, and click **OK** to assign HydroIDs to all WRAPFlowline features (*Click **Yes** to overwrite existing HydroIDs*). When the tool finishes, the range of HydroIDs assigned is displayed.

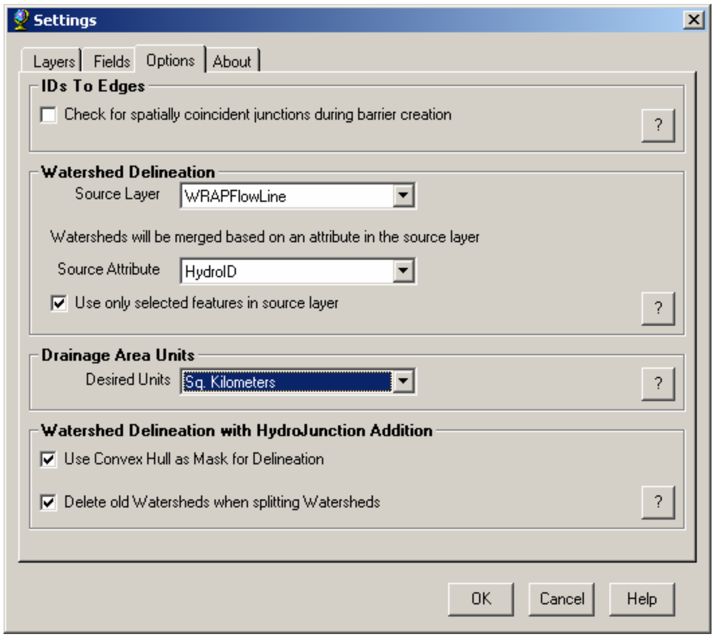


- Be sure that the **Flow Direction** grid appears at the **bottom** of the layers in the table of contents, otherwise you may receive errors when you try to assign the HydroIDs.

5.3 WRAPHydro Process

5.3.1 Delineate catchments for each stream segment in WRAPFlowline

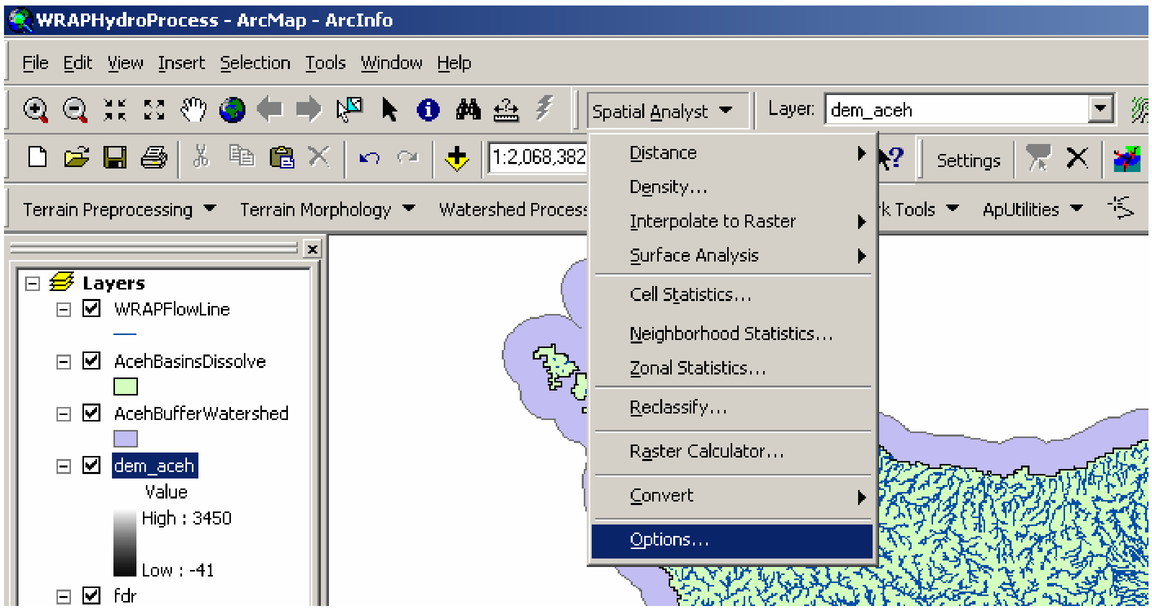
- Add the **WrapHydro toolbar** to the menu.
- In the WRAPHydro toolbar, click **Settings** to open the Settings form and click the **Options** tab.
- In the **Watershed Delineation** section, specify **WRAPFlowLine** as the *Source Layer*, **HydroID** as the *Source Attribute*, and **square kilometers** as the *Desired Units*. Click **OK**.



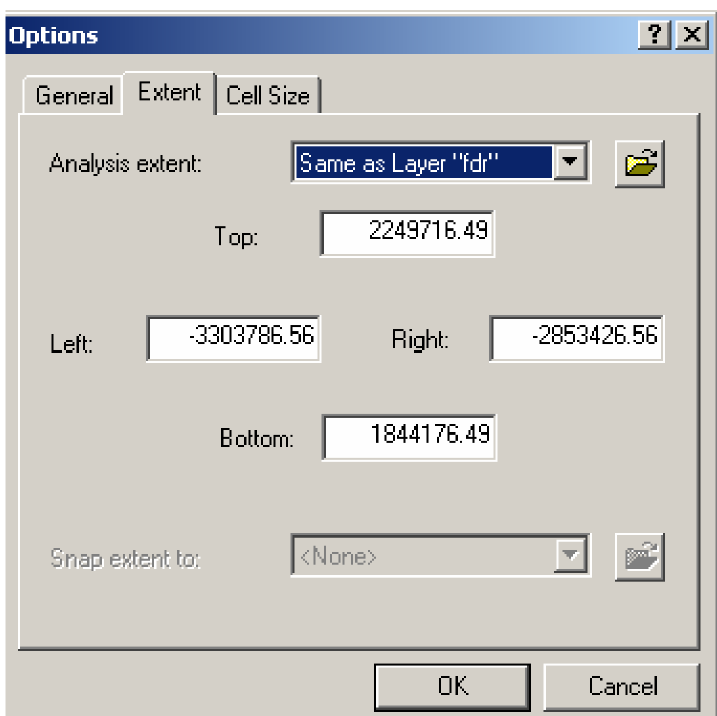
The WRAPHydro tools look at spatial analyst settings when performing raster operations. Therefore, the **extent** and **cell size** should be set in **Spatial Analyst** before delineating watersheds with the WRAPHydro tools.

- Click **Options** in the **Spatial Analyst** toolbar.

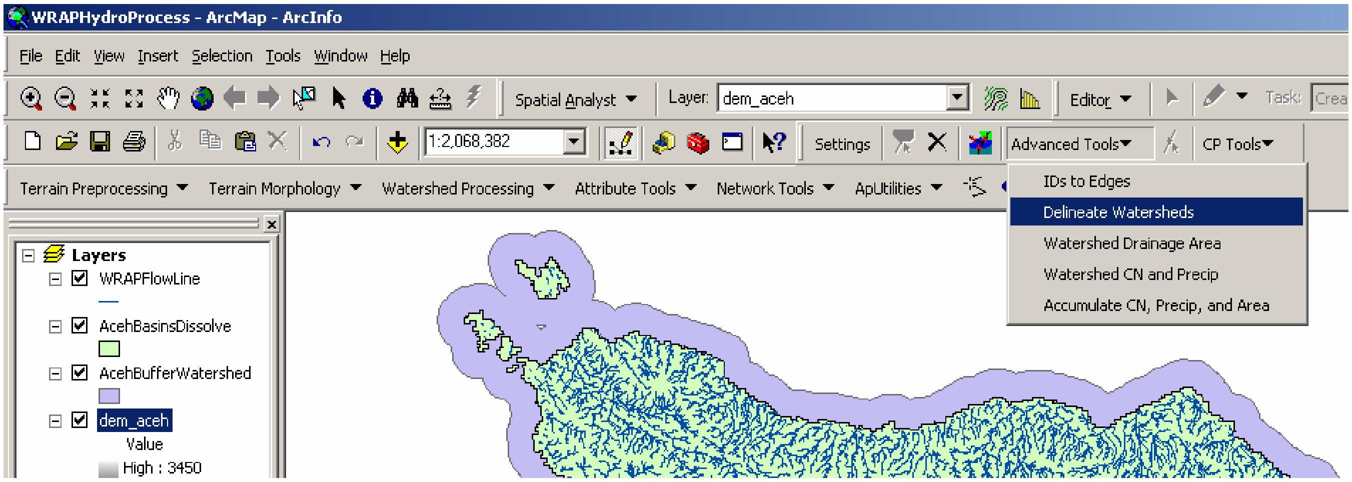
*Hint: If the Spatial Analyst toolbar is not visible, click **View / Toolbars / Spatial Analyst***



- Click the **Extent** tab. Set the *Analysis extent* to **Same as Layer "fdr"**.
- Click the **Cell Size** tab. Set the *Analysis cell size* to **Same as Layer "fdr"**.
- Click **OK**.

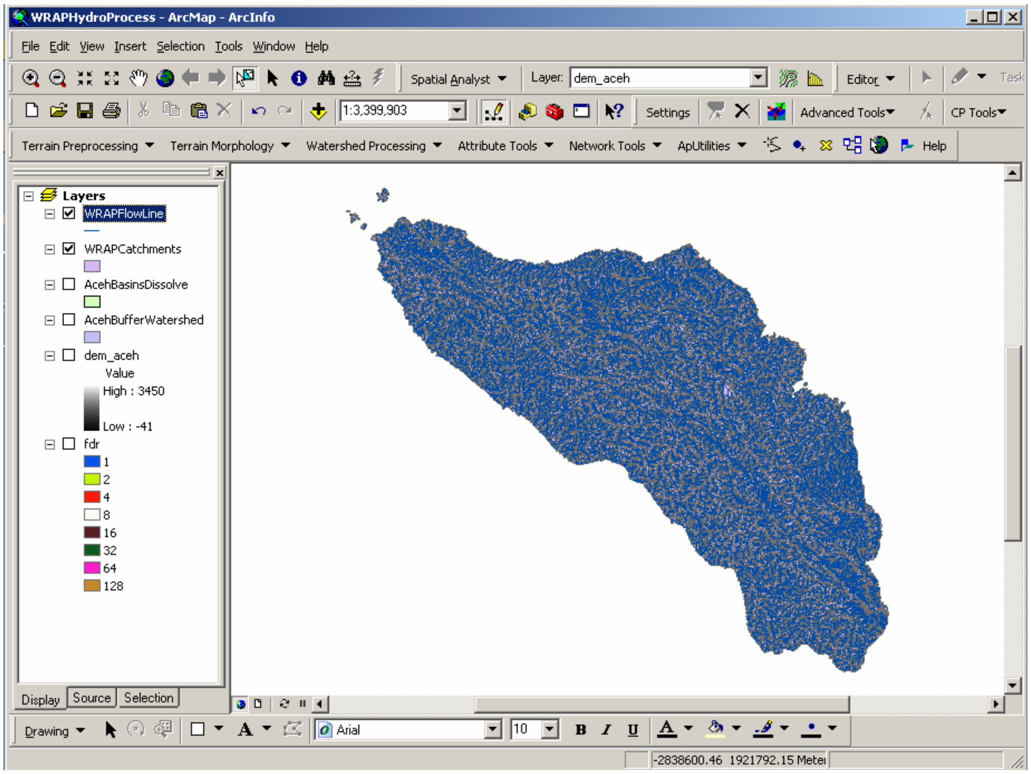


- In the Advanced Tools menu of the WRAPHydro tools, click **Delineate Watersheds**.

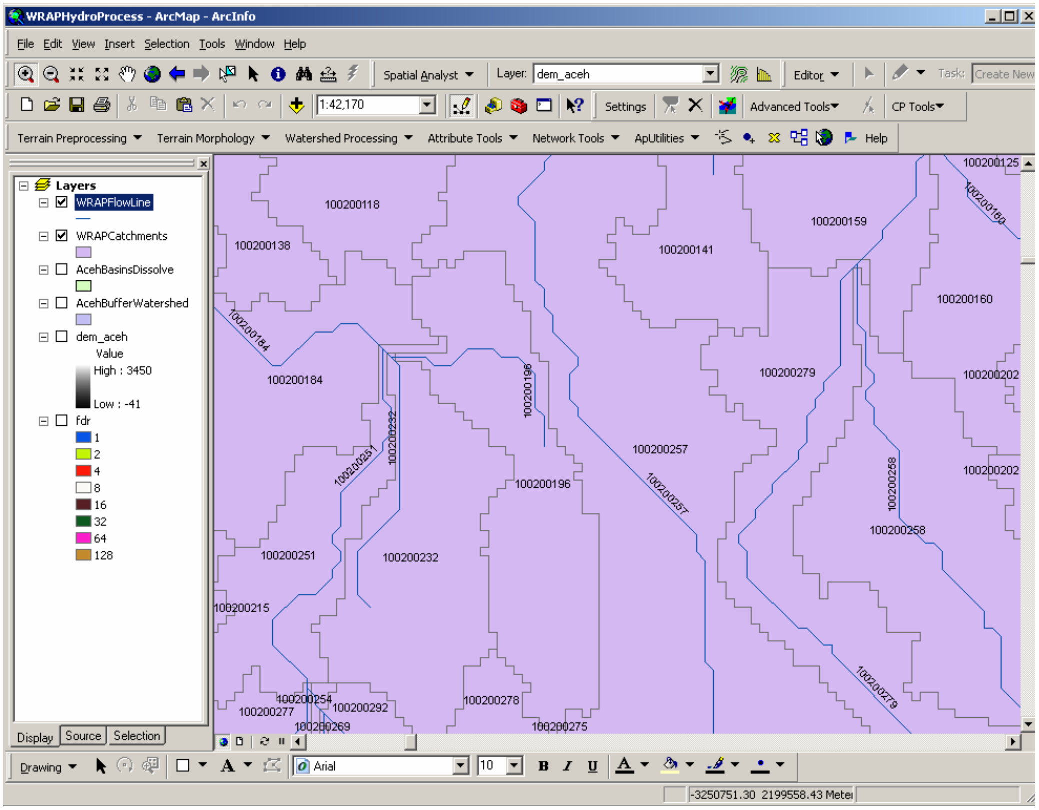


- Save the output watersheds as **WRAPCatchments** into the **PreProcess** feature dataset.

The WRAPHydro tools read the inputs from the Settings form and delineate watersheds. In this case, a WRAPCatchment is created for every WRAPFlowLine feature (Total processing time will be approximately **two hours**).

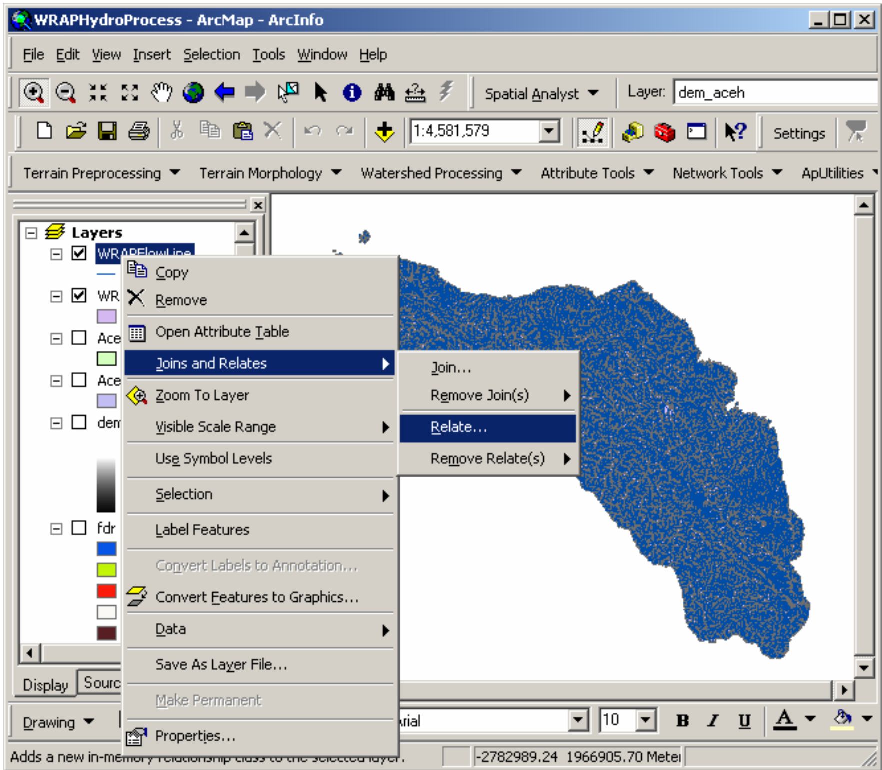


- Check that each delineated watershed has a field **DrainID** which is equal to the **HydroID** of the stream it drains to.

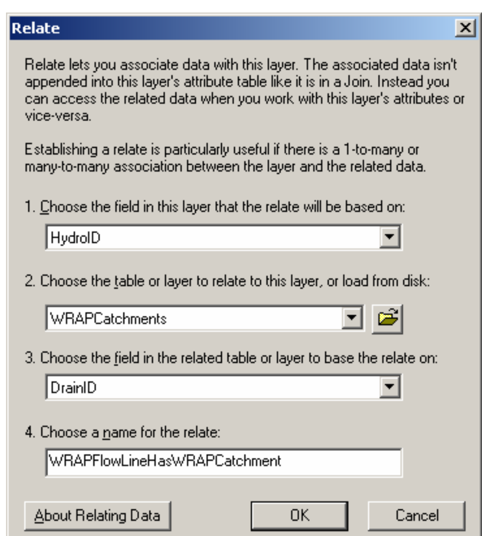


5.3.2 Build a relationship between WRAPFlowline and WRAPCatchment

- In the ArcMap table of contents, right click on the **WRAPFlowLine** feature layer. Click **Joins and Relates / Relate**.



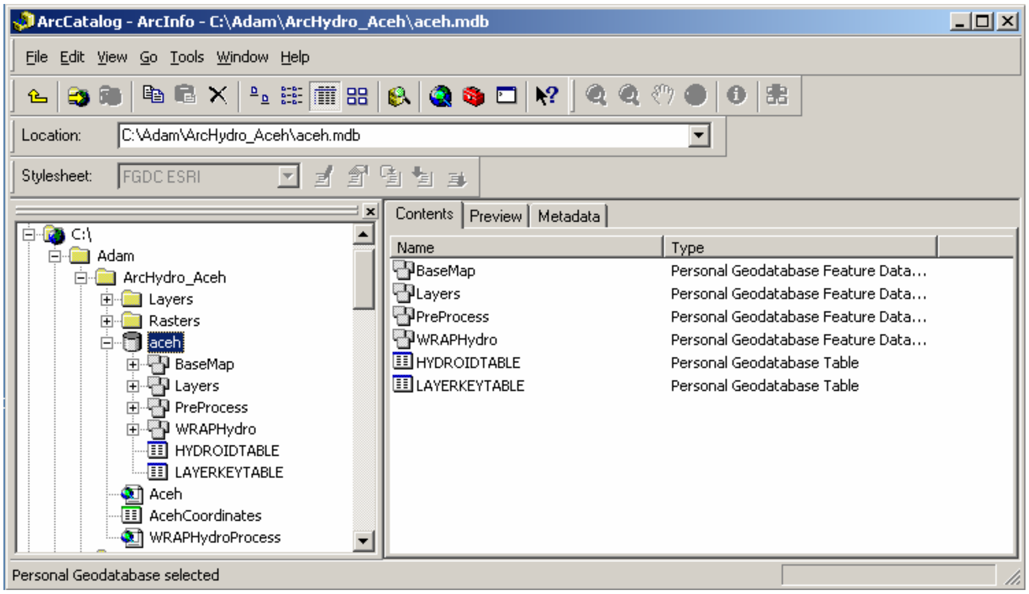
- Choose **HydroID** as the field in WRAPFlowLine that relate will be based on.
- Choose **WRAPCatchments** as the layer to relate to WRAPFlowLine.
- Choose **DrainID** as the key field in WRAPCatchments.
- Type **WRAPFlowLineHasWRAPCatchment** as the relate name. Click **OK**.



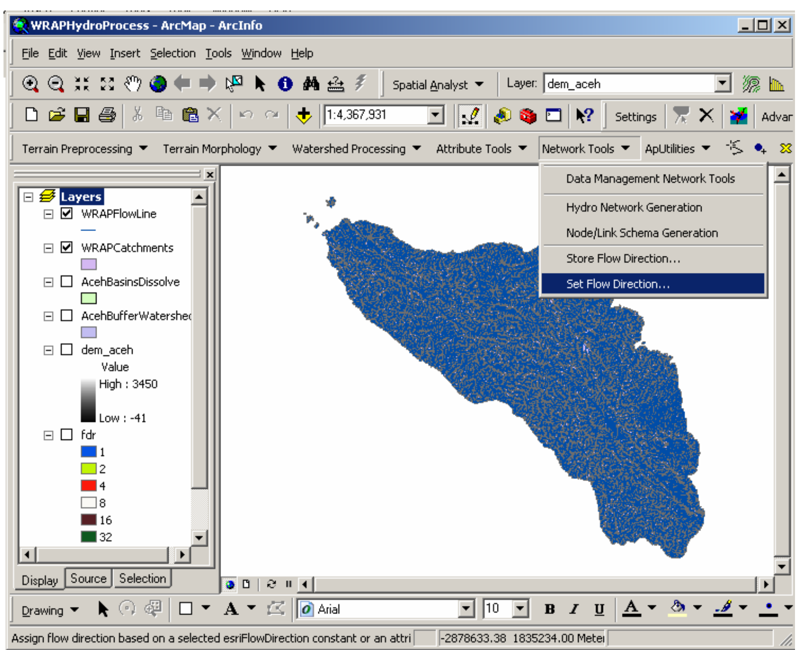
5.3.3 Select streams in the basin and export them to WRAPEdge

Objective: Export all streams that make up the Aceh basin to the WRAPEdge feature class

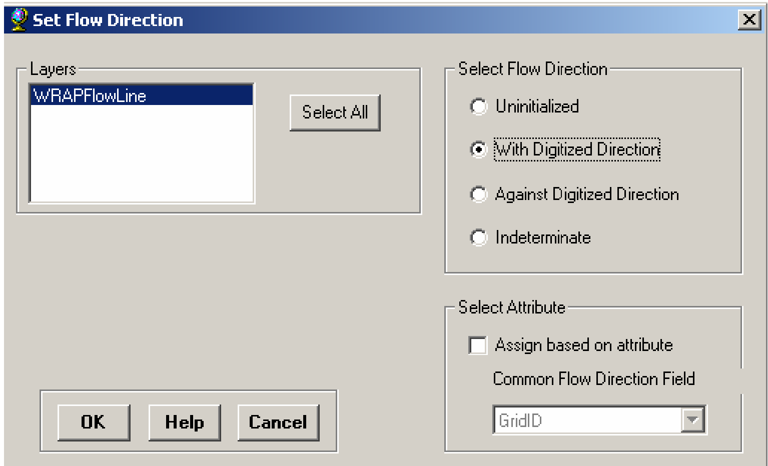
- Close ArcMap and open **ArcCatalog**.
- Create a new feature dataset in the **Aceh.mdb** Geodatabase called **WRAPHydro** with the same geographic properties as the **PreProcess** feature dataset.



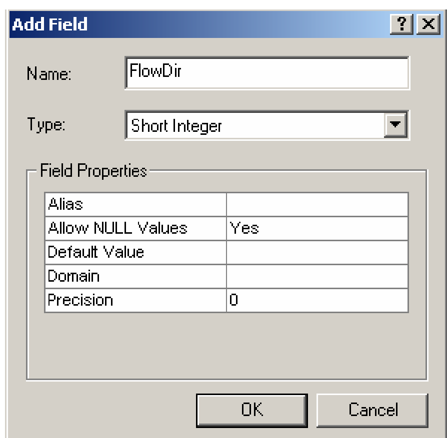
- Close ArcCatalog and reopen the **WRAPHydroProcess** document in ArcMap.
- The flow direction for every FlowLine must be assigned as the first step. Go to the ArcHydro toolbar and then to **Network Tools / Set Flow Direction**.



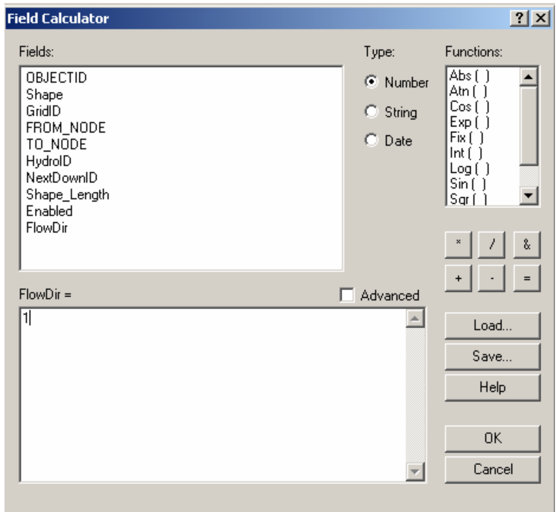
- Select the **WRAPFlowLine** feature class as the *Layers* input file.
- Select **With Digitized Direction** for the method to *Select Flow Direction*. Click **OK**.



- Select **Start Editing** in the Editor toolbar.
- Open the **WRAPFlowLine** attribute table and select **Options / Add Field**. Name the new field **FlowDir** and select **Short Integer** as the field type. Click **OK**.

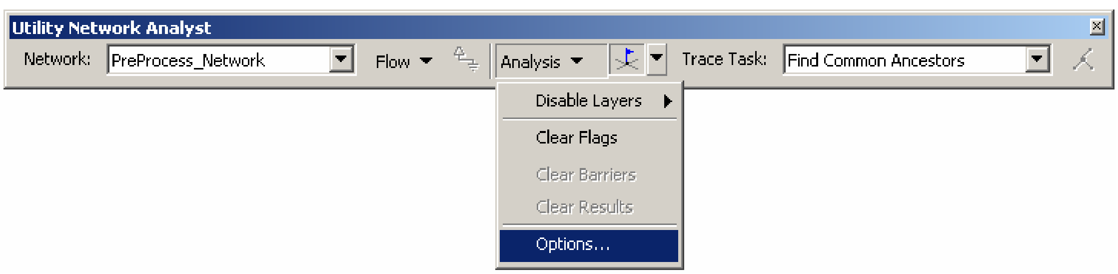


* Right click on the name **FlowDir** at the top of the new field. Select **Calculate Values** and assign a value of "**1**" to every entry in the FlowDir field. Click **OK** and then **Stop Editing** in the Editor toolbar. **Close** the attribute table.

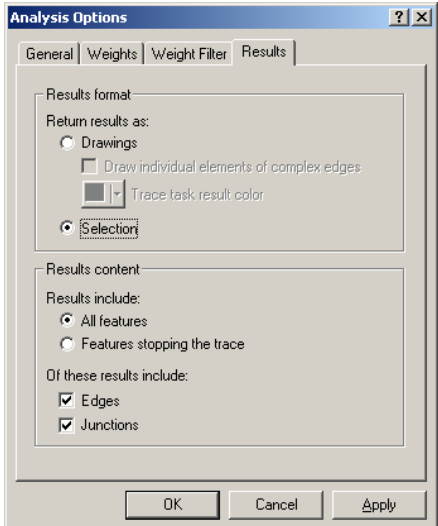


To select all of the WRAPCatchments that make up the Aceh basin, we need to initially select all of the streams that lie in the basin. These streams are selected by placing a flag at the outlet of the basin, and then tracing upstream. The **Utility Network Analyst** must first be configured to return the results of the trace as a selection.

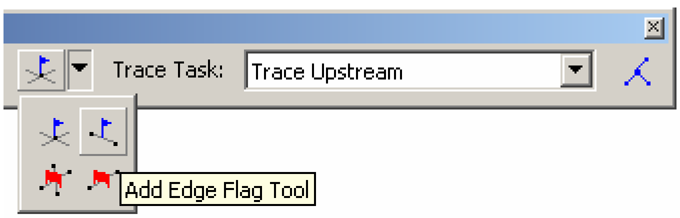
* In the **Utility Network Analyst** toolbar, click **Analysis** / **Options**.



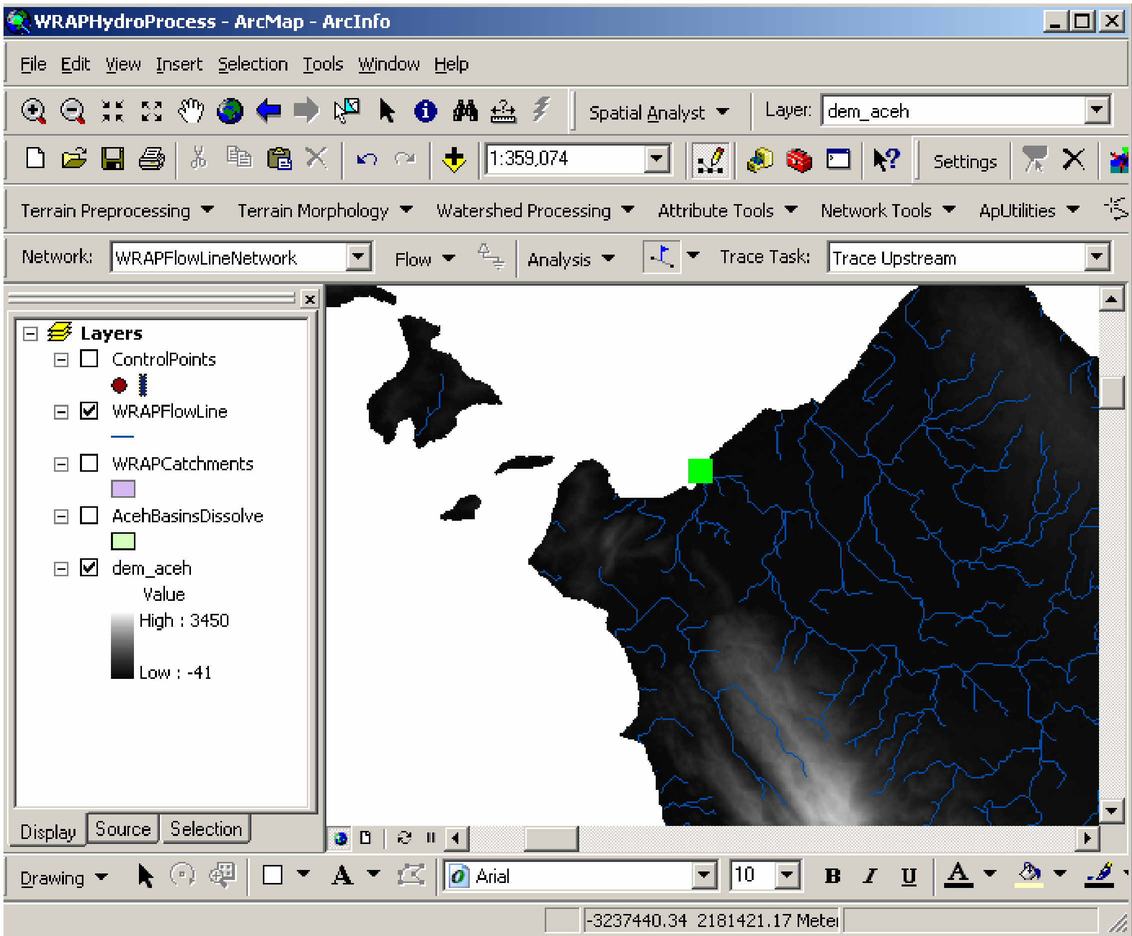
- In the **Results** tab, choose **Selection** for the *Results format*. Select **all features**, including **edges** and **junctions** for the *Results content*. Click **OK**.



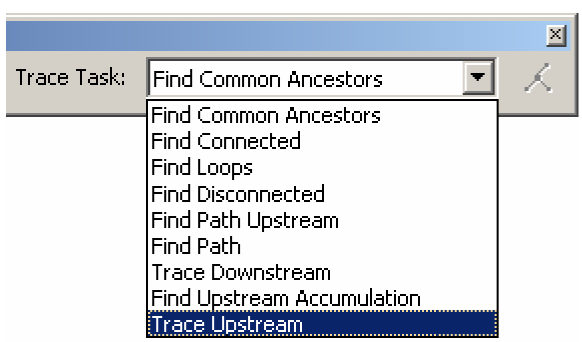
- Select the **Add Edge Flag Tool** from the **Utility Network Analyst** toolbar.



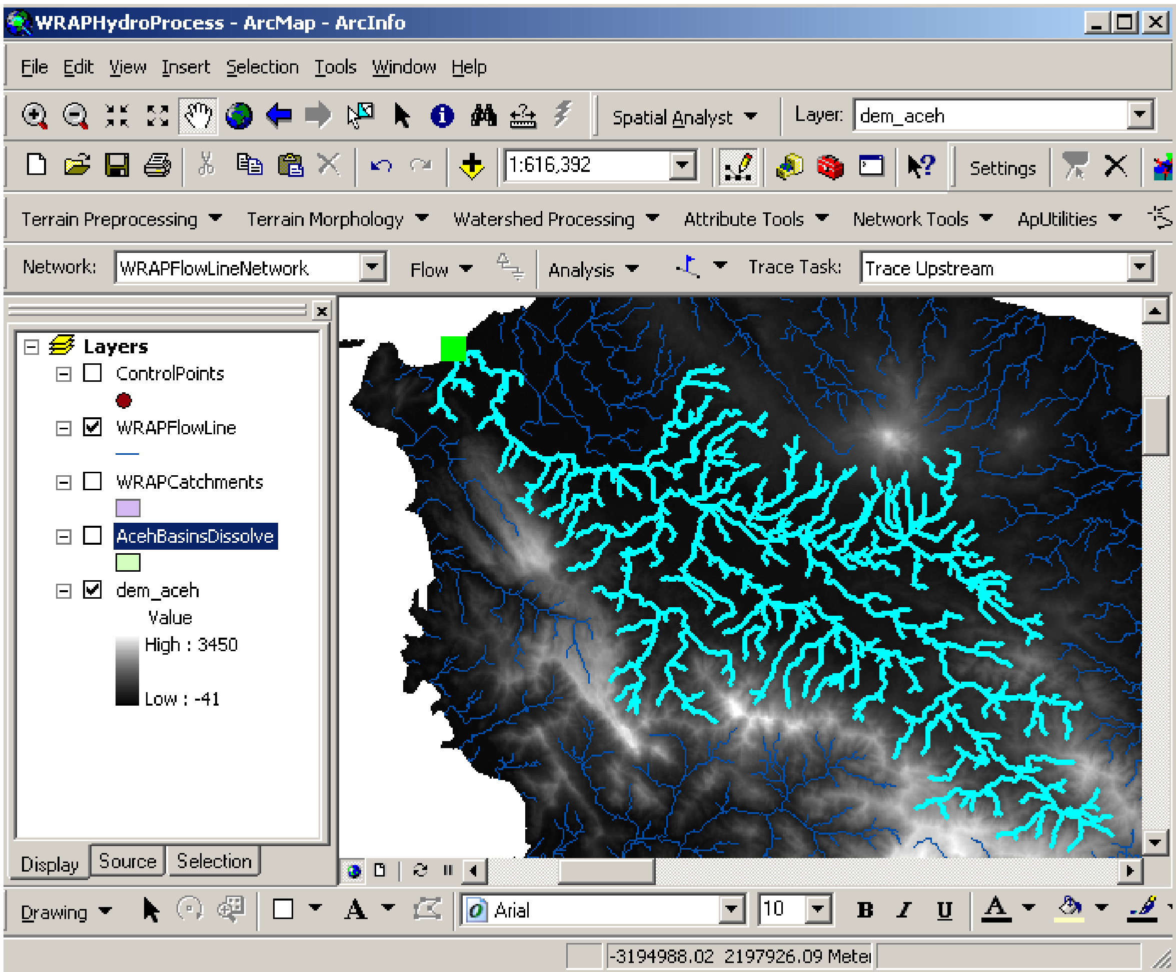
- Place a flag at the most downstream location in the Aceh basin by clicking near the downstream end of the last edge in the basin. This location is shown in the image below. Note that this location is also just upstream of the most downstream FlowLine in the basin because the WRAPFlowLine feature class includes a 10 kilometer buffer. The original polygon describing the Aceh subbasin can be added as a reference.



- Select **Trace Task** / **Trace Upstream** from the **Utility Network Analyst** toolbar.



- Click the **Solve** button on the **Utility Network Analyst** toolbar to perform the trace. All of the WRAPFlowLines that are on the stream network for the Aceh basin will be selected.

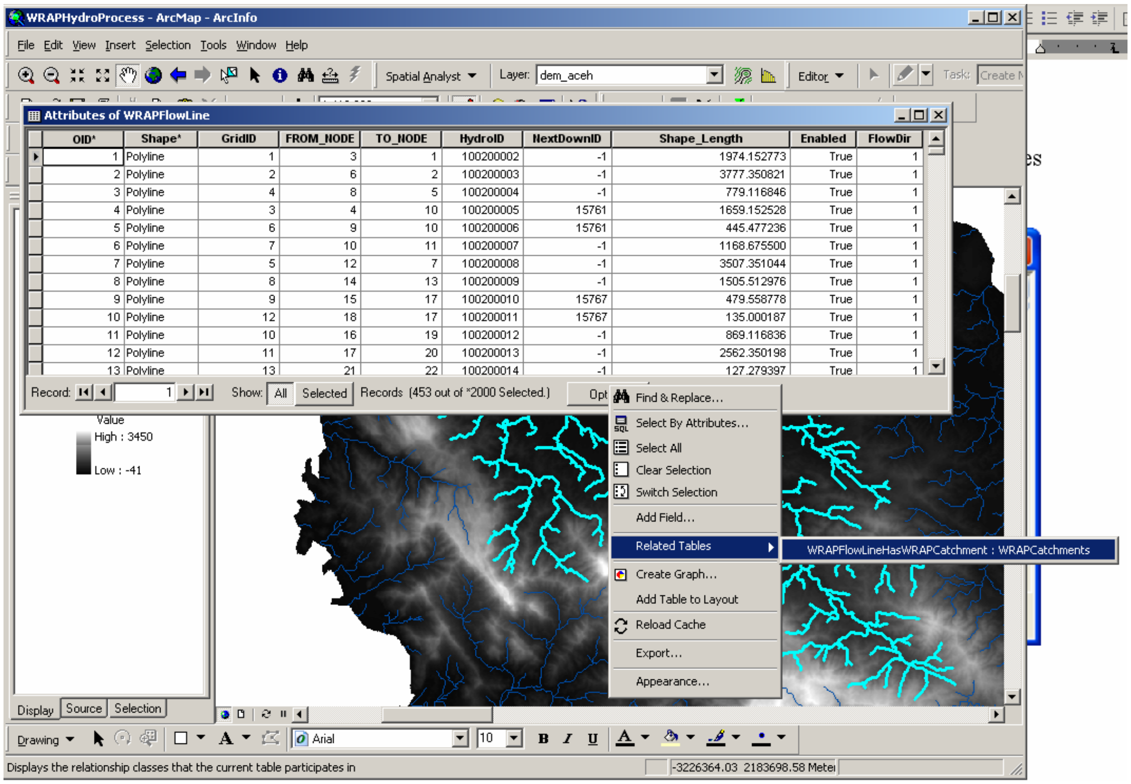


- Export the **WRAPFlowLines** to the WRAPHydro feature dataset and call the result **WRAPEdge**.

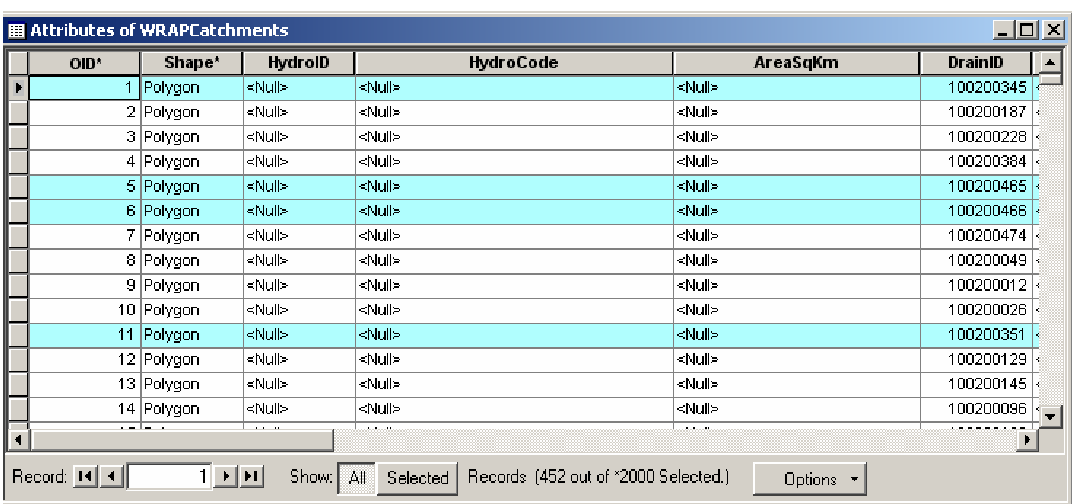
5.3.4 Select the catchments that drain to the selected streams.

Objective: Identify all WRAPCatchments that drain to the steams of the Aceh basin

- Right click on the **WRAPFlowLine** layer in the ArcMap table of contents and click **Open Attribute Table**.
- Click **Options / Related Tables** and select the relationship to **WRAPCatchments**.



The **WRAPCatchments attribute table** appears automatically and the items related to the selected **WRAPFlowLines** are highlighted.



Attributes of WRAPCatchments

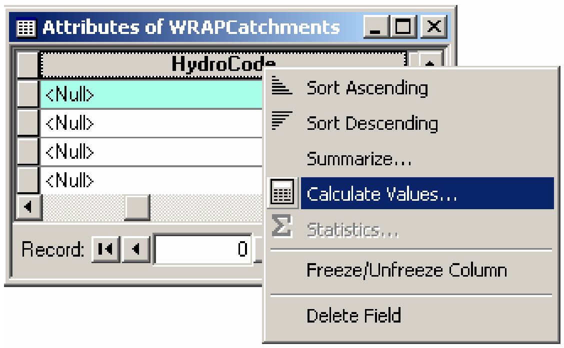
OID*	Shape*	HydroID	HydroCode	AreaSqKm	DrainID
1	Polygon	<Null>	<Null>	<Null>	100200345
2	Polygon	<Null>	<Null>	<Null>	100200187
3	Polygon	<Null>	<Null>	<Null>	100200228
4	Polygon	<Null>	<Null>	<Null>	100200384
5	Polygon	<Null>	<Null>	<Null>	100200465
6	Polygon	<Null>	<Null>	<Null>	100200466
7	Polygon	<Null>	<Null>	<Null>	100200474
8	Polygon	<Null>	<Null>	<Null>	100200049
9	Polygon	<Null>	<Null>	<Null>	100200012
10	Polygon	<Null>	<Null>	<Null>	100200026
11	Polygon	<Null>	<Null>	<Null>	100200351
12	Polygon	<Null>	<Null>	<Null>	100200129
13	Polygon	<Null>	<Null>	<Null>	100200145
14	Polygon	<Null>	<Null>	<Null>	100200096

Record: 1 Show: All Selected Records (452 out of *2000 Selected.) Options

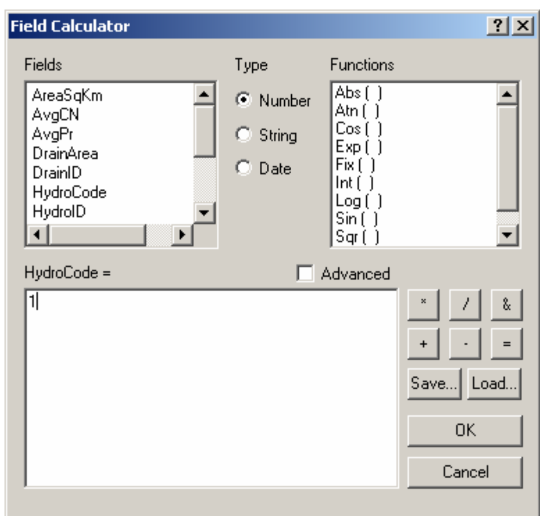
5.3.5 Dissolve the selected WRAPCatchments into a single basin

Objective: Dissolve the selected WRAPCatchments to create a single polygon 'basin' which defines the boundary of the Aceh Basin

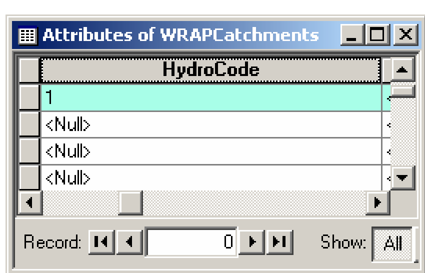
- Open the attribute table for **WRAPCatchments** and right click the **HydroCode** field. Click on **Calculate Values**.



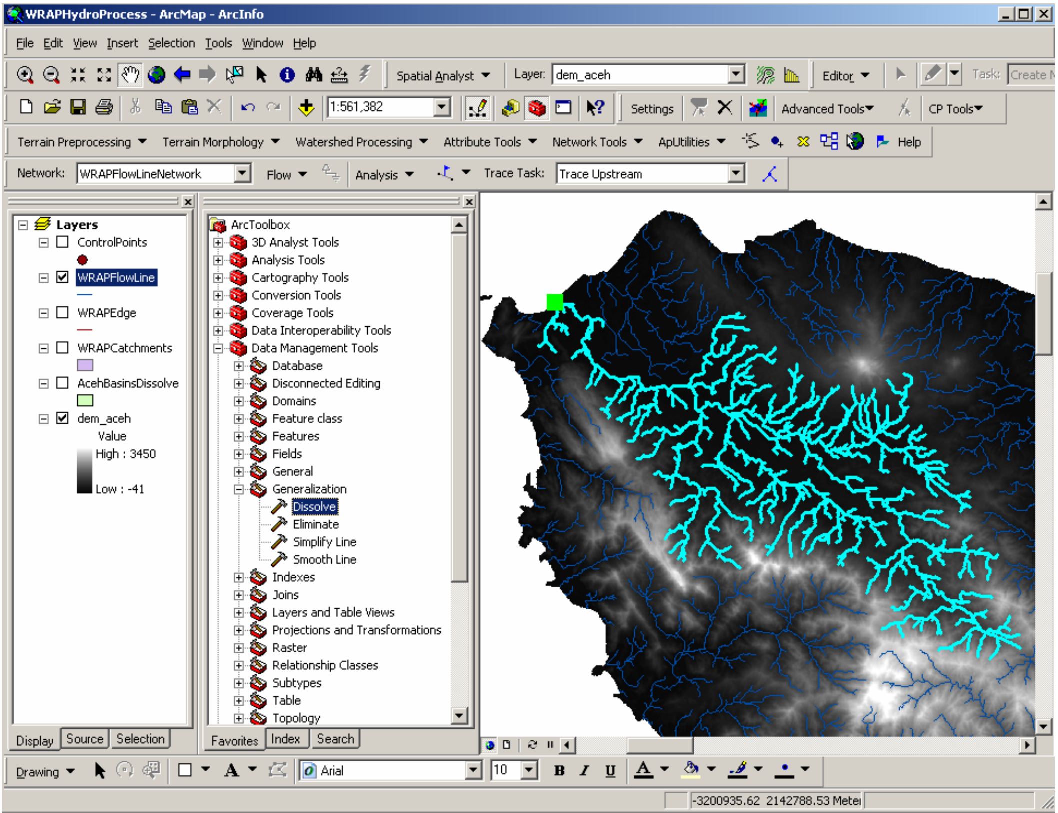
- Assign the number **1** to the **HydroCode** in the field calculator. The field calculator will only operate on selected WRAPCatchments.



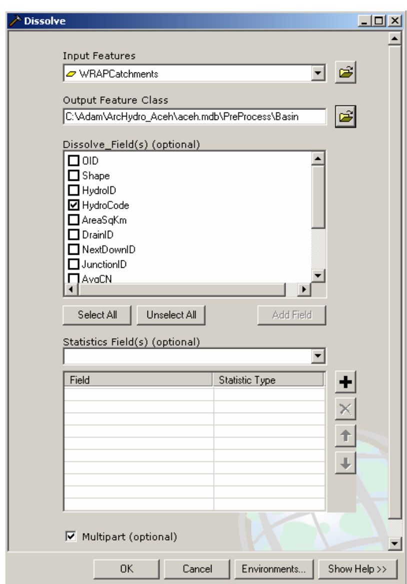
Now all selected **WRAPCatchments** have a **HydroCode** of **1**.



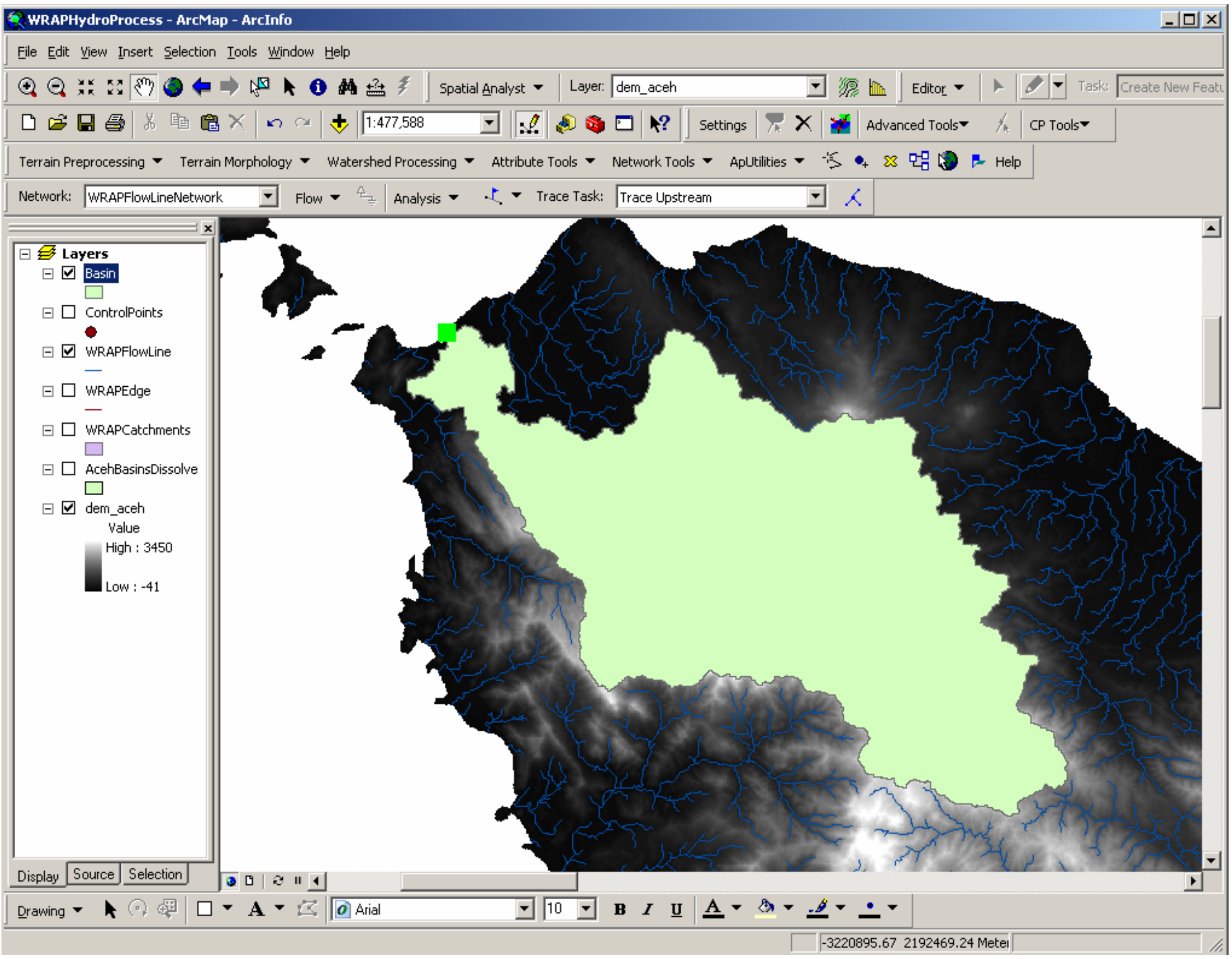
- Close the attribute table and launch the **ArcToolbox** application. Go to **Data Management Tools / Generalization / Dissolve**.



- Select the **WRAPCatchments** as the *Input Features* layer. Give the *Output Feature Class* the name **Basin** and save it in the **PreProcess** feature dataset. Select the *Dissolve Fields* based on the **HydroCode** attribute. Click **OK**.



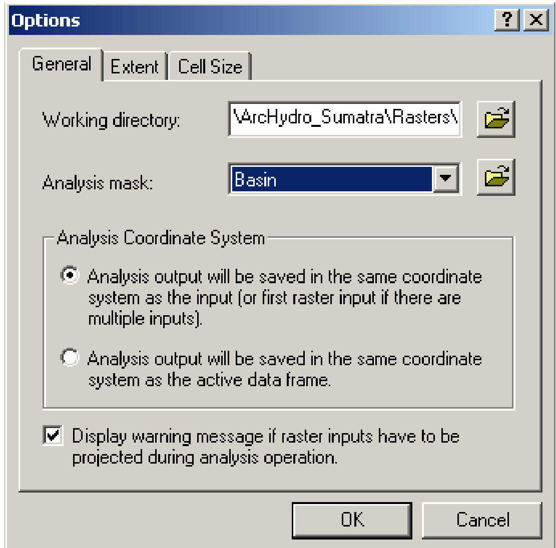
The **Basin** feature class now stores the **Aceh River basin**.



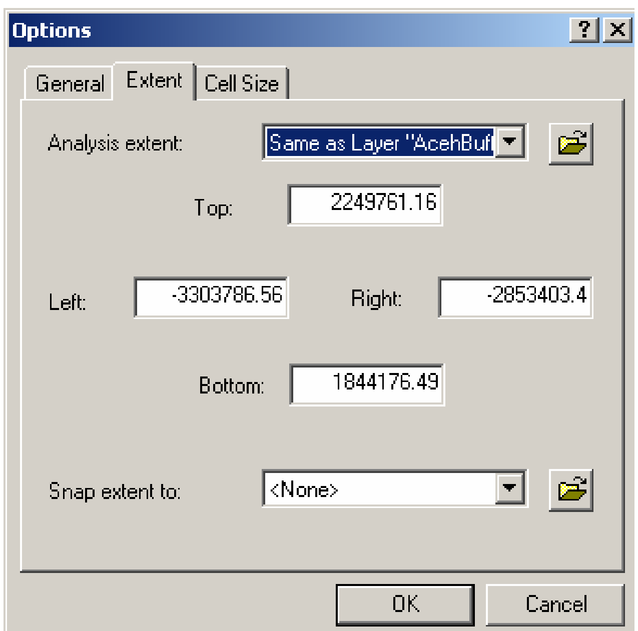
5.3.6 Clip Regional Grids to Basin

5.3.6.1 Set the analysis parameters

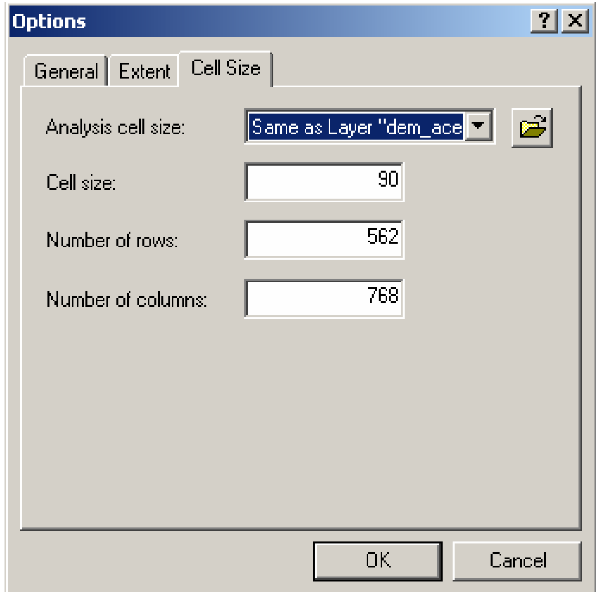
- Set the analysis parameters in **ArcMap / SpatialAnalyst / Option**. Set the *Analysis Mask* to the **Basin**.



Set the *Extent* of the output to be the same as the layer **AcehBufferWatershed**.

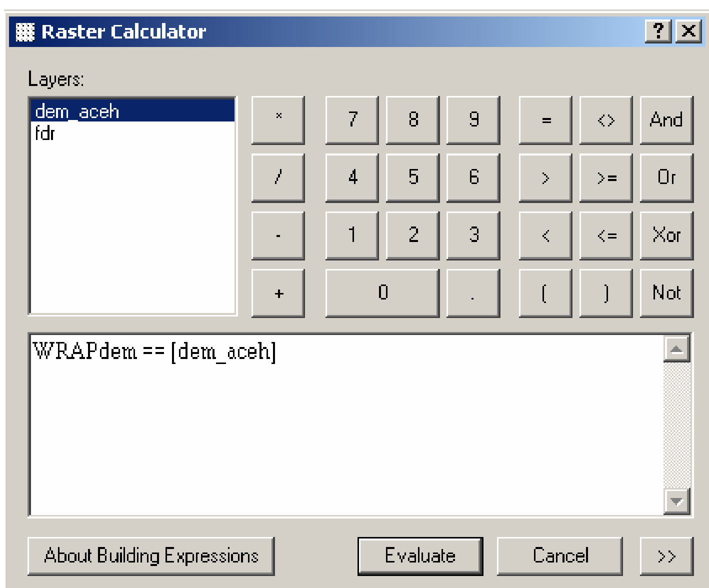


- Set the *Cell Size* to be the same as the input DEM (**dem_aceh**). Click **OK**.

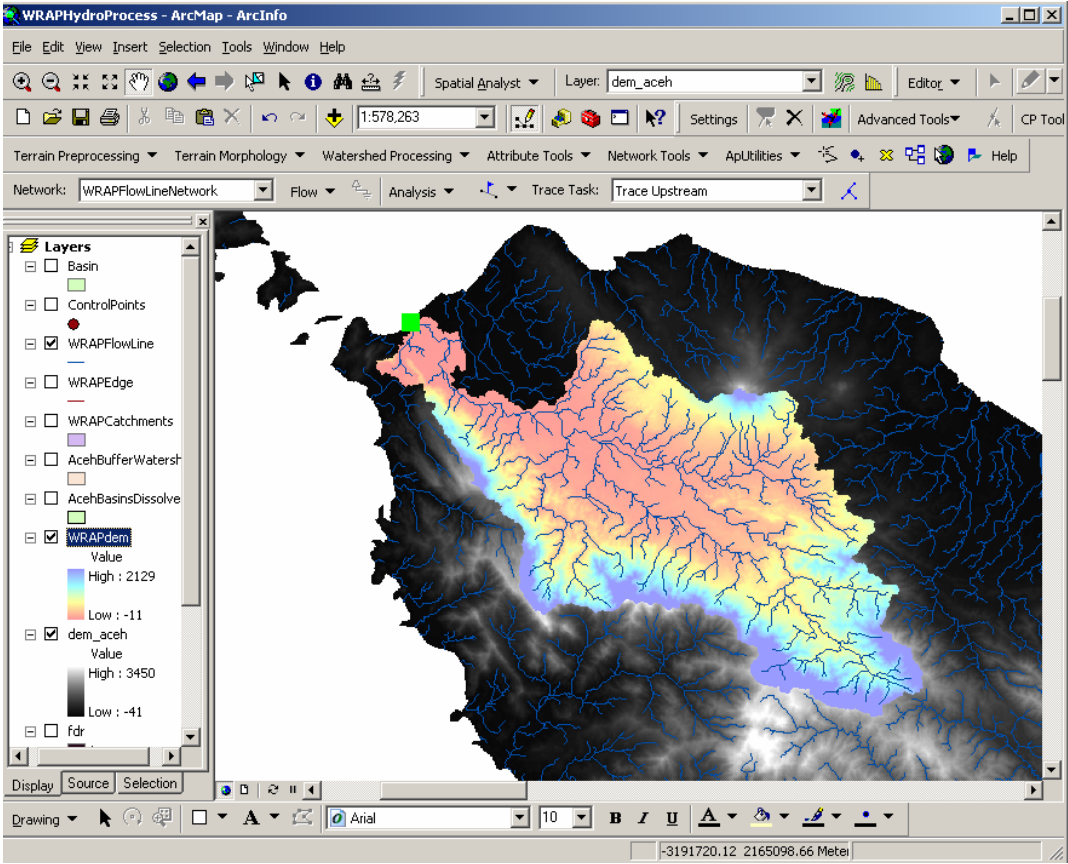


5.3.6.2 Clip DEM to Basin with Buffer

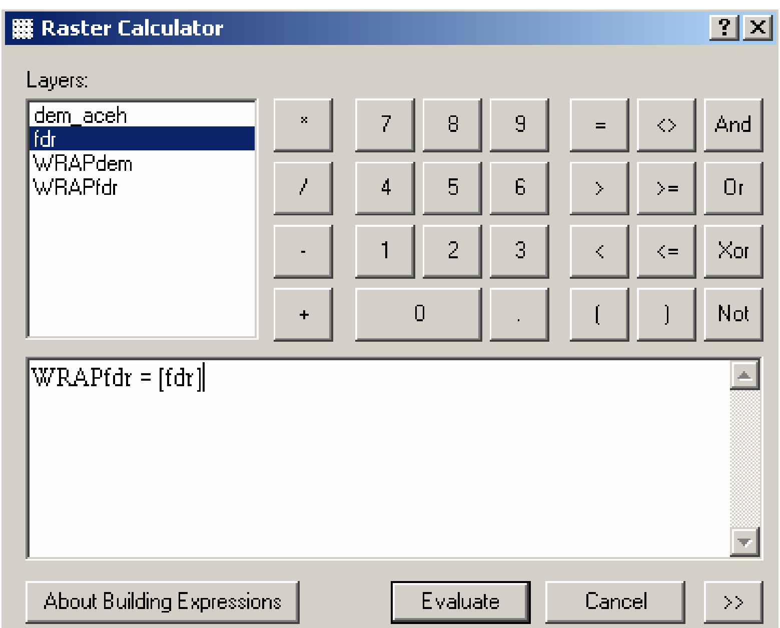
- Open **Spatial Analyst / Raster Calculator**. Clip the basin raster **dem_aceh** to the area of the **Basin** layer. Click **Evaluate**.

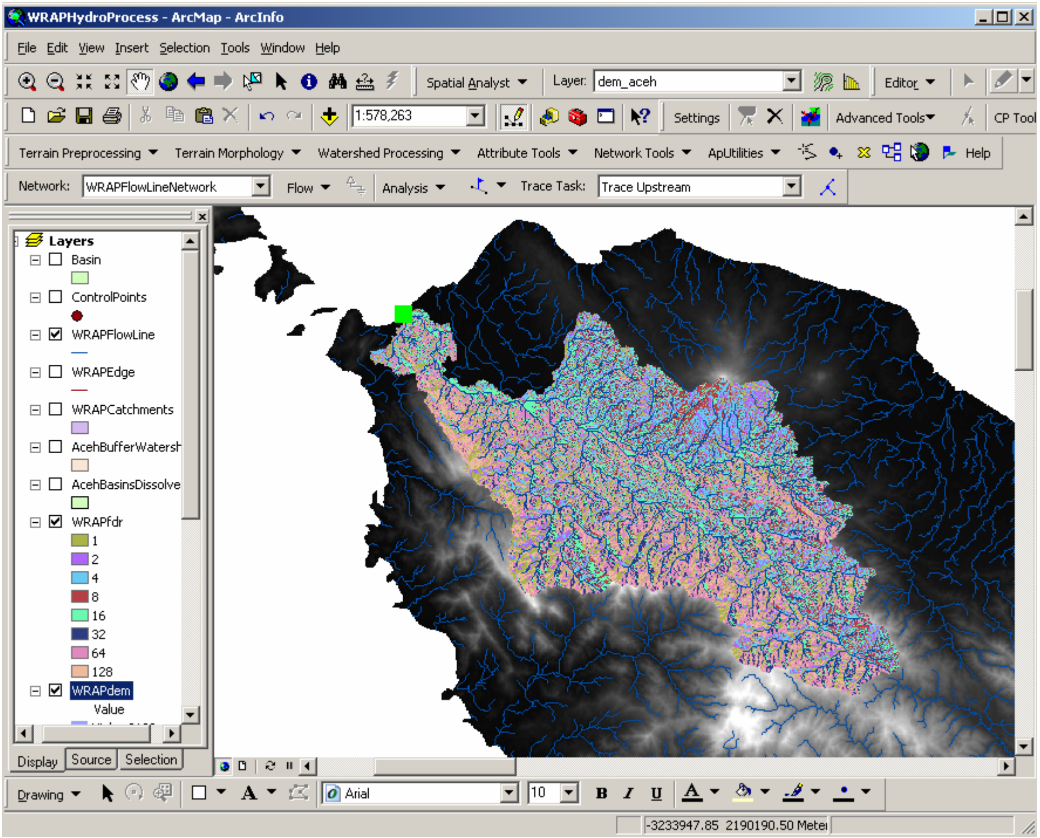


The result is:



- Clip the Flow Direction Grid to the analyst mask using **Raster Calculator.**



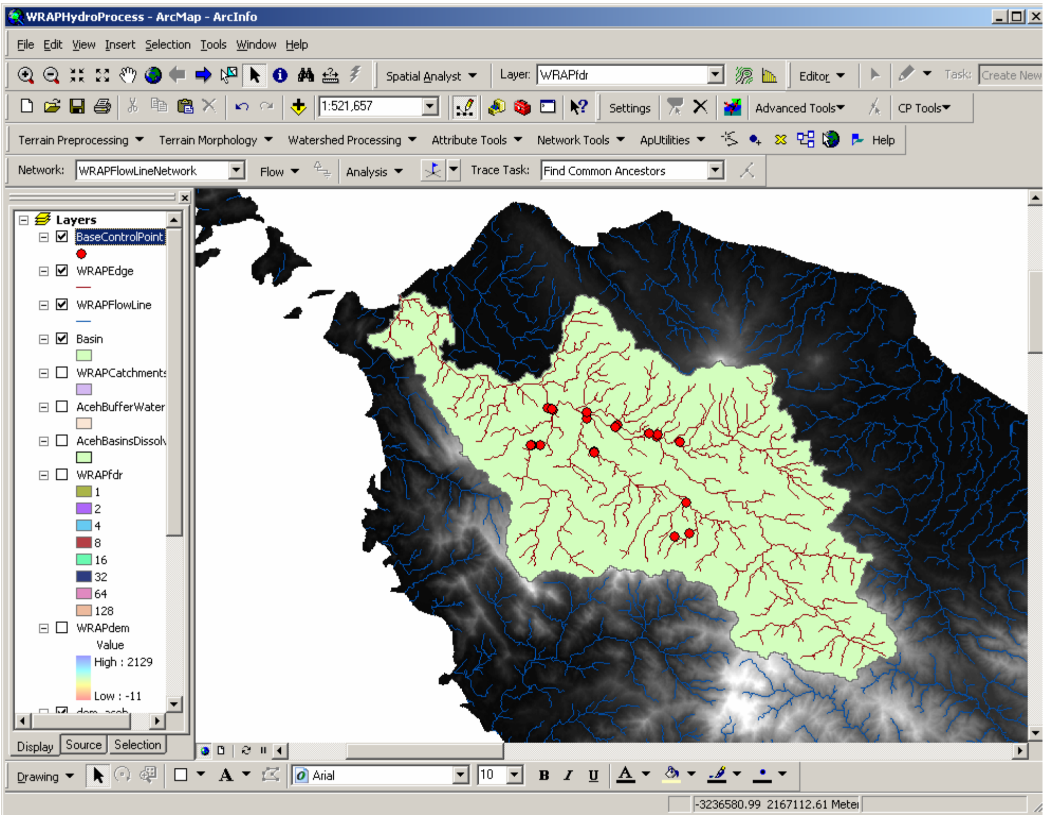


The grids used for WRAPHydro analysis are now clipped to cover the Aceh Basin exactly.

5.3.7 Create SnapControlPoint feature class in BaseMap

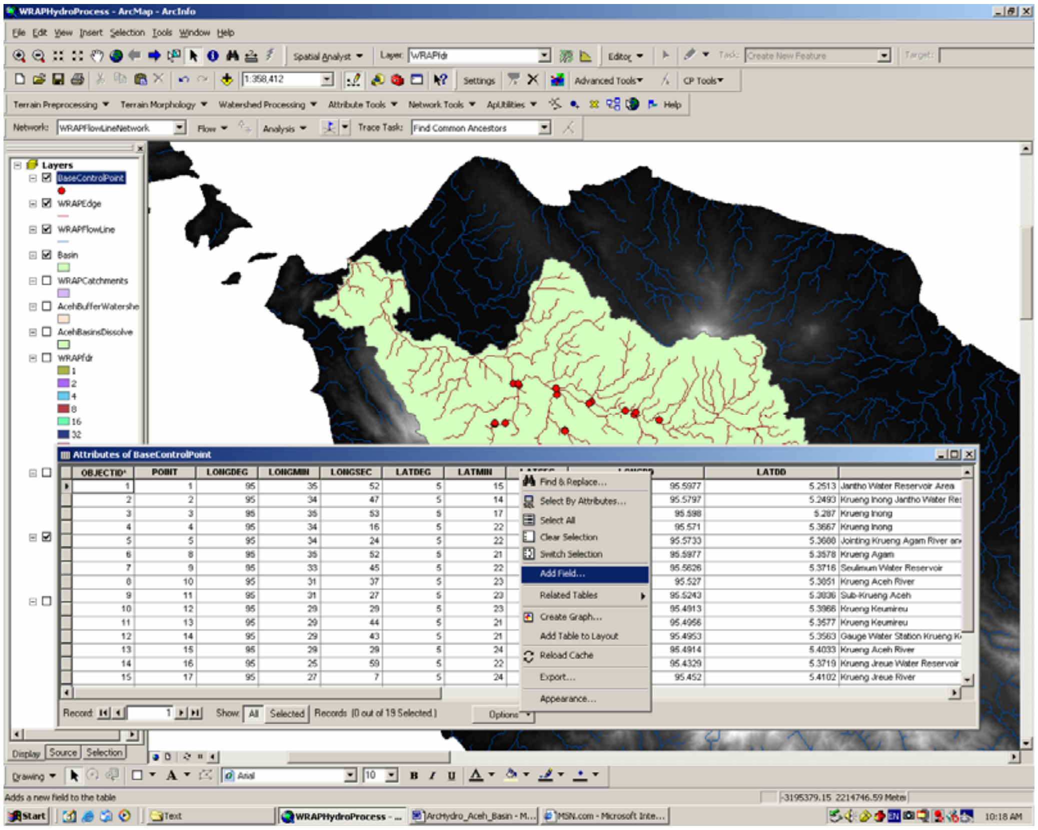
Objective: Create a SnapControlPoint feature class using the BaseControlPoint feature class

- Close ArcMap and open **ArcCatalog**.
- Export the **BaseControlPoint** shapefile from the **Participant** folder to the **BaseMap** feature dataset as a new feature class and call it **BaseControlPoint**. Close ArcCatalog.
- Open your document **WRAPHydroProcess.mxd** in ArcMap and add the **BaseControlPoint** feature class.

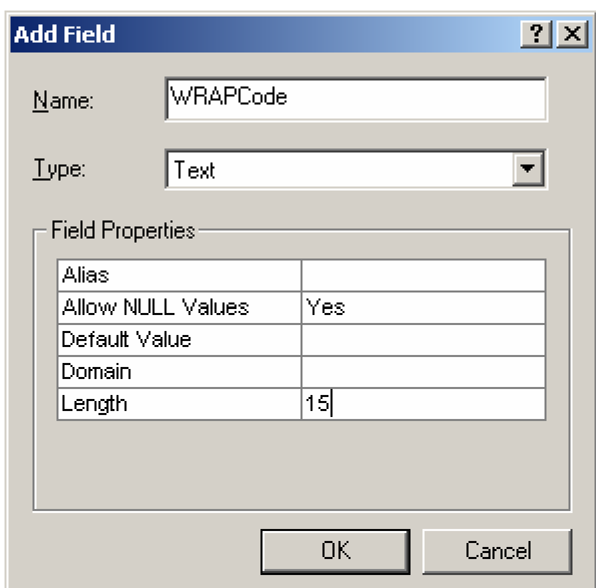


- Open the attribute table of **BaseControlPoint**. It should contain the following fields (add them if necessary): **DrainageArea** (double), **LengthDown** (double), **AvgCN** (Double), **AvgPR** (double), **JunctionID** (long int), **HydroID** (long int), **NextDownID** (long int).

- Click **Options / Add Field** to add one final field.

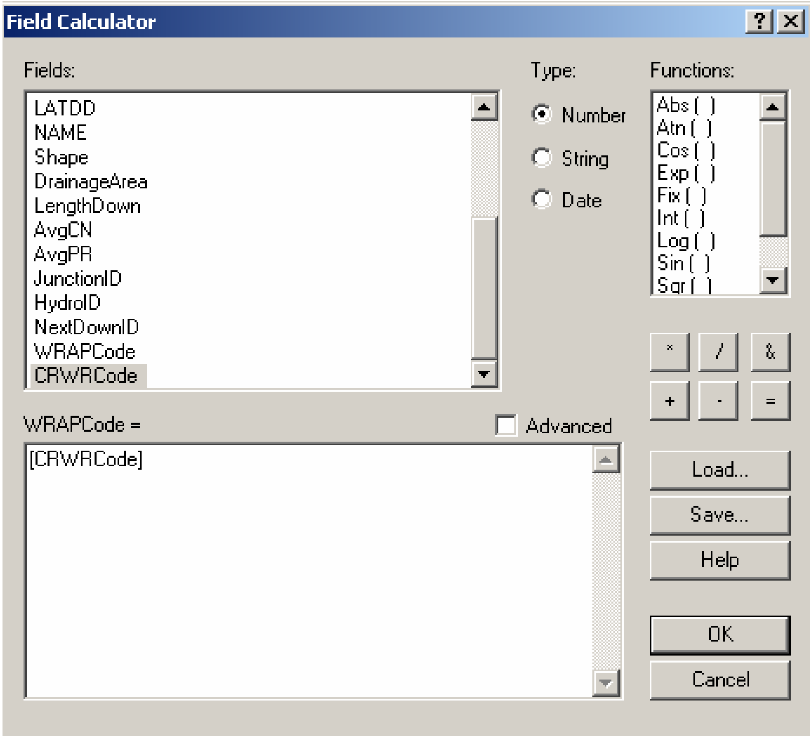


- Call the field **WRAPCode** and make it of type **Text** (15 digits length). Click **OK**. We will use this field as an identifier key field later on.

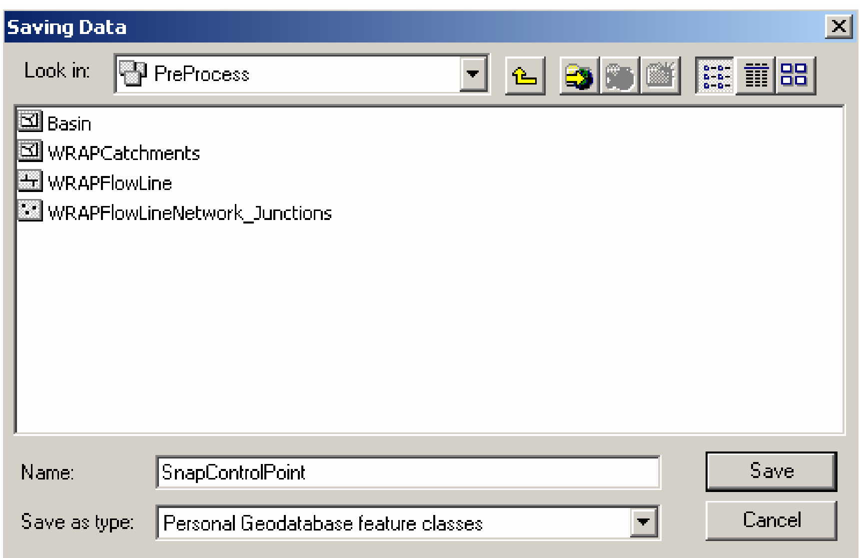


- Right click on the **WRAPCode** field and click **Calculate Values**.

- Copy the values from the **CRWRCode** field into **WRAPCode** using the field calculator. Click **OK** and close the attribute table.

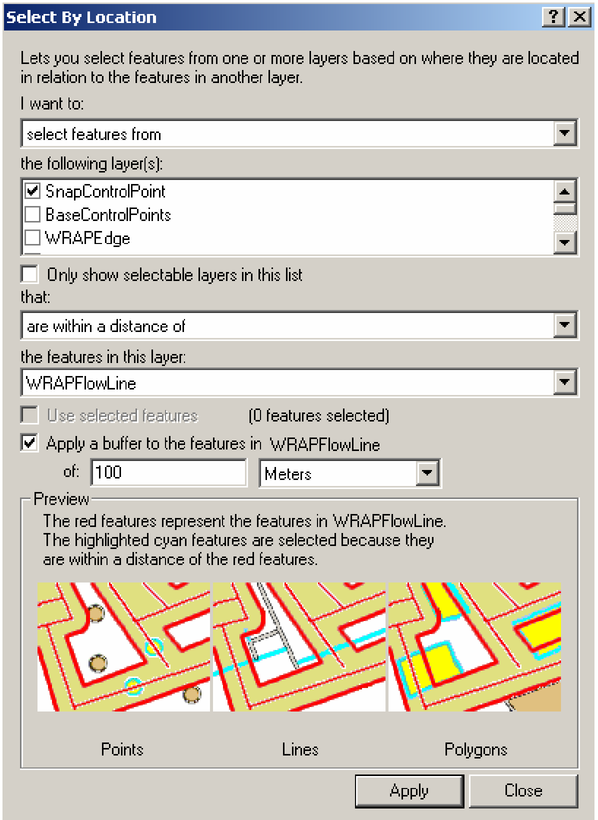


- Right click on the **BaseControlPoint** feature class and select **Data / Export Data**.
- Call this new feature class **SnapControlPoint** and save it in the **PreProcess** feature dataset. Click **OK**.



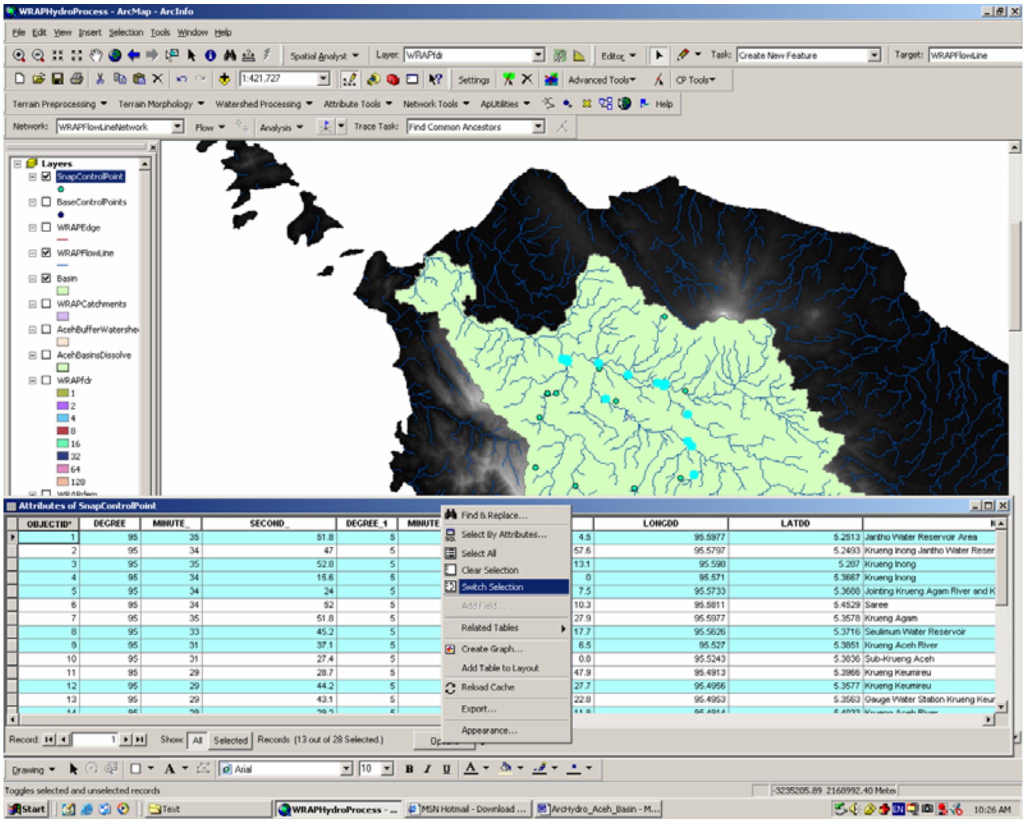
- Start an edit session if one has not already been started (**Editor / Start Editing**).

- In the upper menu of ArcMap go to **Selection / Select by Location**. Select **SnapControlPoints** that are "*within a distance of*" the feature **WRAPFlowLine** and *apply a buffer to the features* of **100 meters**. Click **Apply** (the process for selection will take about 1-2 minutes) and then **Close**.



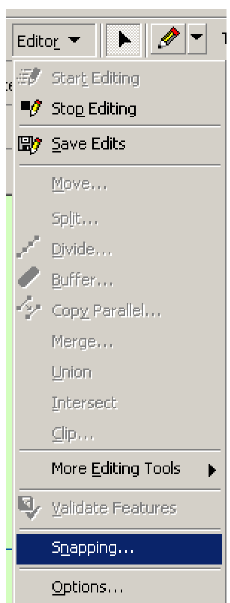
Now all of the SnapControlPoints within 100 m of WRAPFlowLine are selected. However, we want to isolate those points that are further than 100 m from WRAPFlowLine.

- Open the **SnapControlPoint** attribute table.
- Click **Options / Switch Selection**.

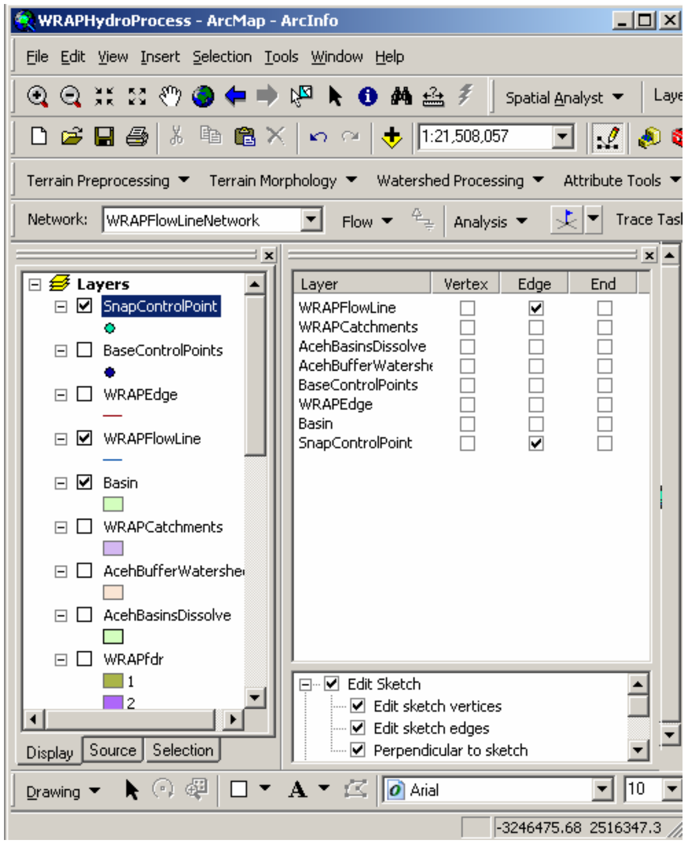


Now the SnapControlPoints further than 100 m from WRAPFlowLine are selected.

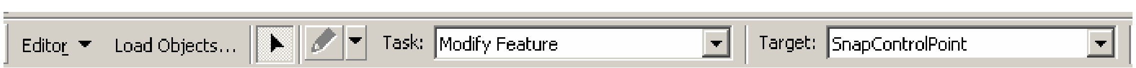
- Go to **Editor / Snapping**



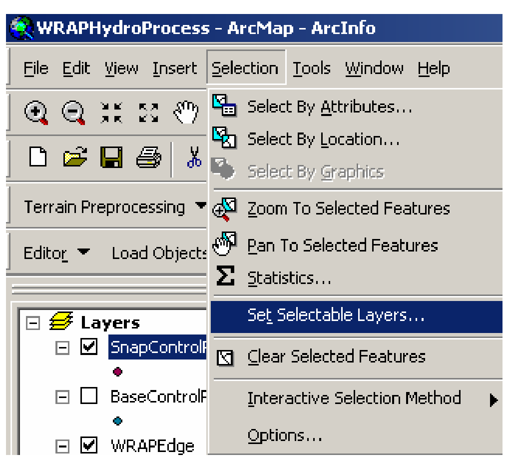
- Check the **SnapControlPoints**, **WRAPFlowLine**, and **Edit Sketch** boxes



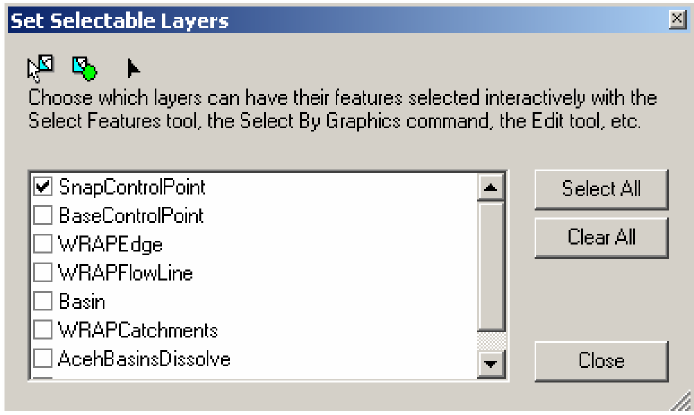
- In the **Editor Toolbar**, select **Modify Feature** as the *Task* and **SnapControlPoint** as the *Target*.



- Go to the **Selection** menu and select **Set Selectable Layers….**

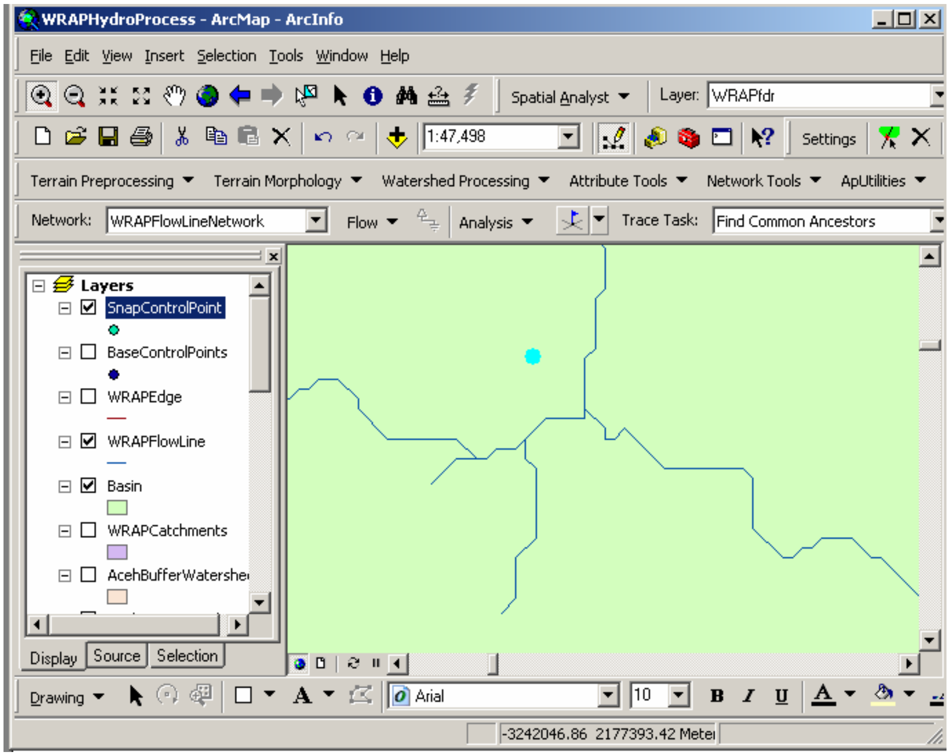


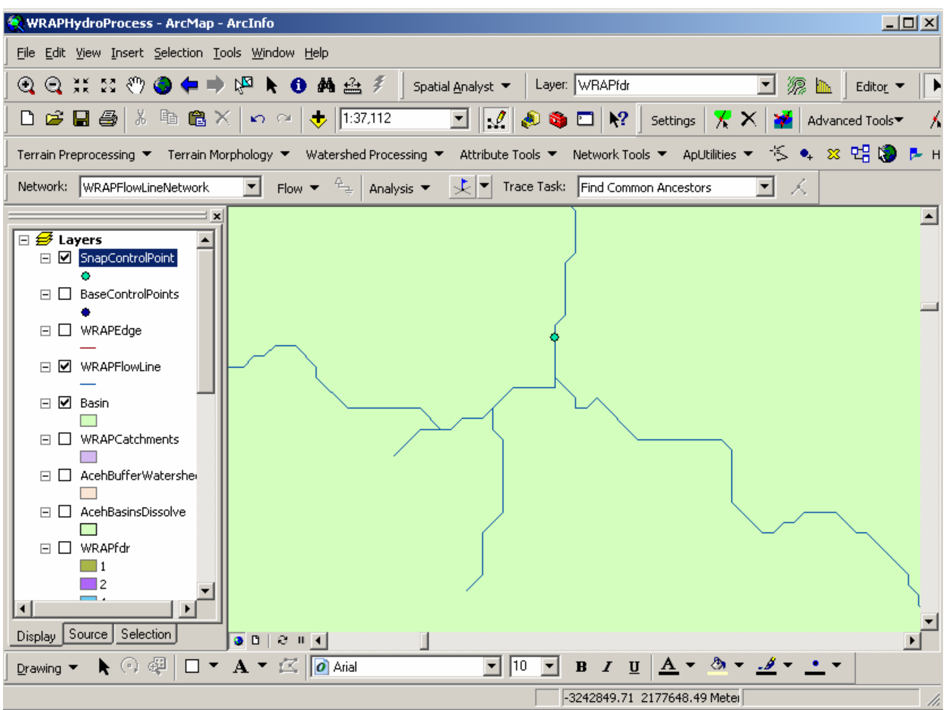
- Clear all selections and check only the **SnapControlPoint** layer. Click **Close**.



- Now we are ready to move points! Use the **Zoom In** tool to view the selected points close up. Click on the **Edit Tool** and click away from the point (so that it is no longer highlighted). Click on the previously selected **SnapControlPoints** and drag within **100 m** of the nearest **WRAPFlowLine** (or an otherwise appropriate location on the stream network).

Note: If you leave all of the points highlighted, they will all move when you attempt to move any one highlighted point.



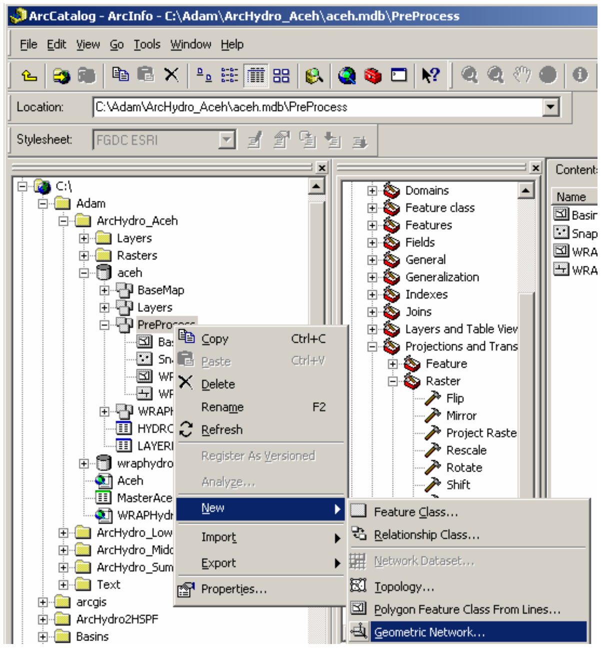


- Go to **Editor / Stop Editing** once all points have been moved.

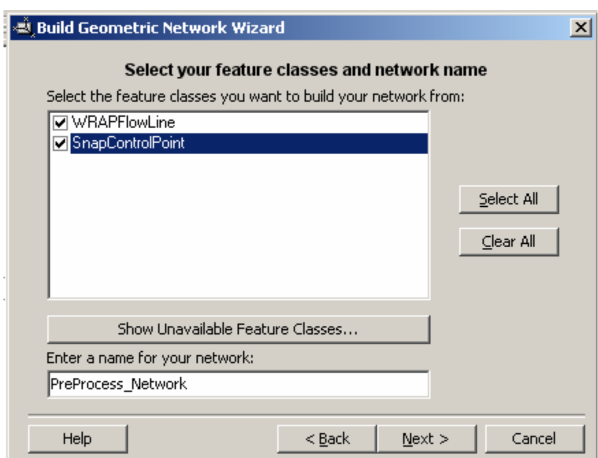
5.3.8 Build new network with SnapControlPoint and WRAPFlowline

Objective: Delete the old network and build a new one with SnapControlPoint and WRAPFlowline, and snap the junctions to the edges by giving a 100 m snapping tolerance.

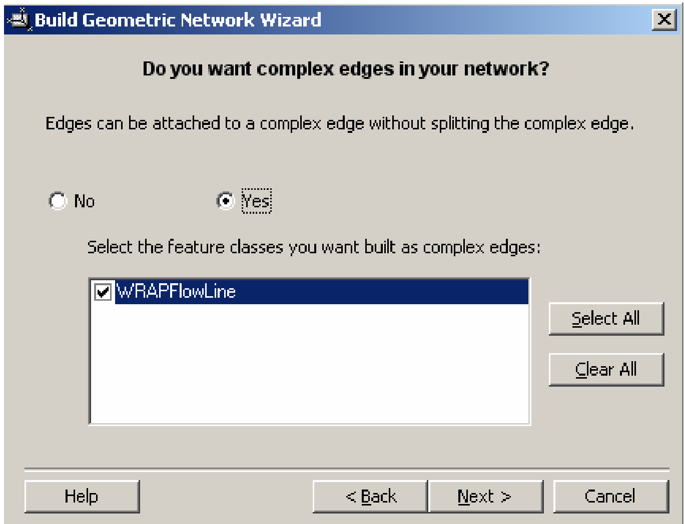
- Save and close **ArcMap**.
- Open **ArcCatalog**. Go to the **Aceh** Geodatabase / **PreProcess** feature dataset / **WRAPFlowLineNetwork**. Right click on **WRAPFlowLineNetwork** and click **Delete** to delete the network.
- Right click on the **PreProcess** feature dataset and go to **New** / **Geometric Network**.



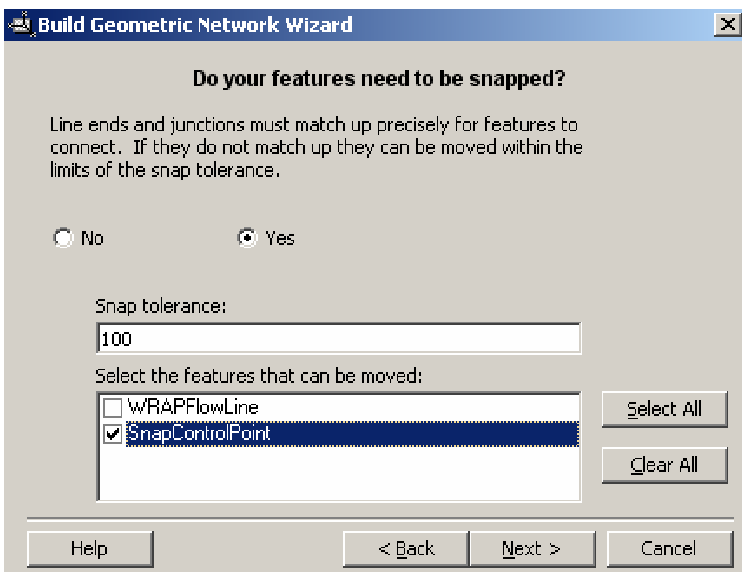
- Choose to *Build a geometric network from existing features* and click **Next**.
- Select the **WRAPFlowLine** and **SnapControlPoint** feature classes to build the network from and name the network **PreProcess_Network**. Click **Next**.



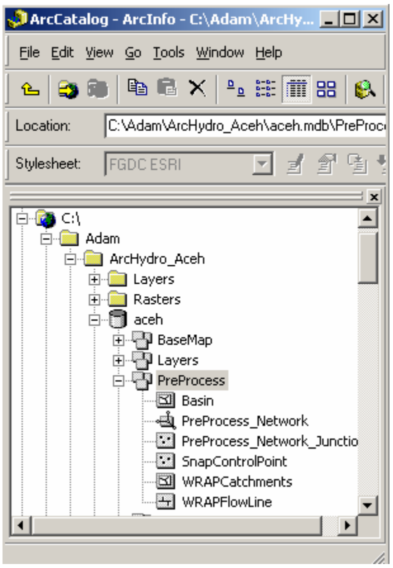
- Click **Yes** to preserve existing enabled values. Click **Next**.
- Click **Yes** to include complex edges in the network. Click **Next**.



- Click **Yes** to select the snap option and choose the **SnapControlPoint** feature class to be moved with a snap tolerance of **100**. Click **Next**.



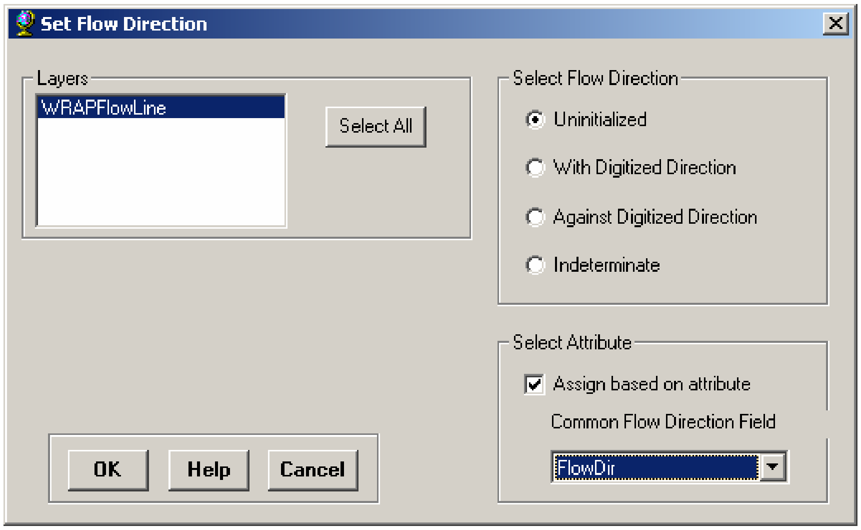
- Do not specify any sources, sinks, or weights for the network (Click **No** on both slides). Click **Finish** to complete the Build Geometric Network Wizard process. When completed, all SnapControlPoints should be snapped on top of a WRAPFlowLine and you will see the **PreProcess_Network** in the Preprocess feature dataset.



5.3.9 Assign Flow Directions

Objective: Assign flow directions to WRAPFlowLines

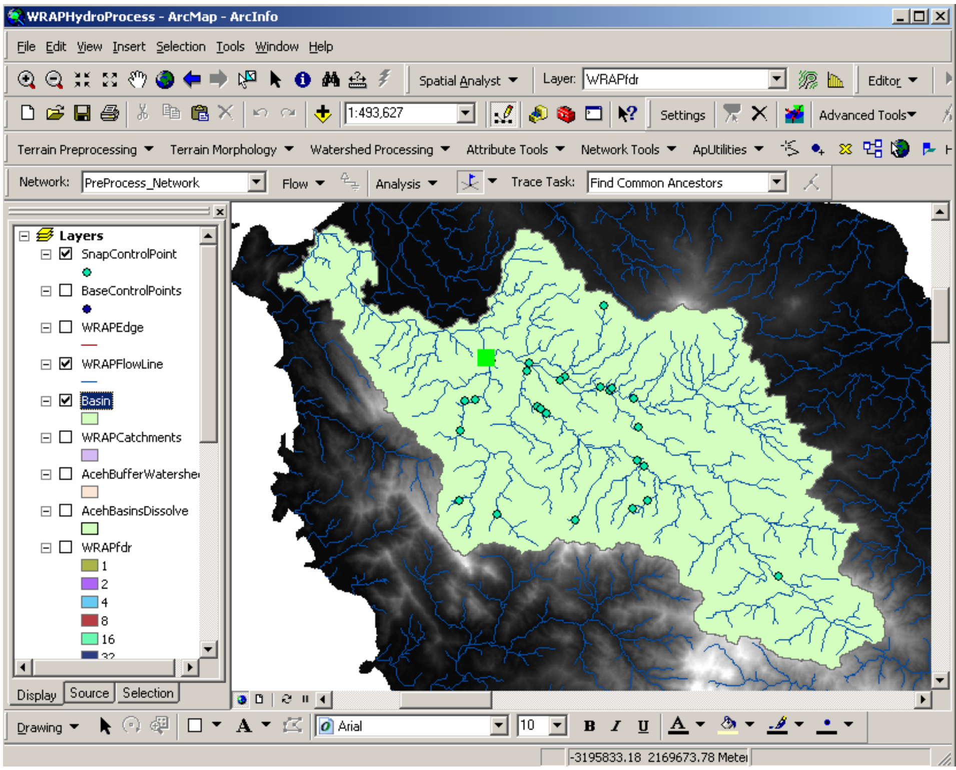
- Close **ArcCatalog**.
- Open the **WRAPHydroProcess** project in **ArcMap**.
- In the **ArcHydro** toolbar, click **Network Tools / Set Flow Direction**.
- Select the **WRAPFlowLine** as the input for the *Layers* field, leave the *Select Flow Direction* field as **Uninitialized**, and assign the flow direction based on the **FlowDir** attribute in the *Select Attribute* field. Click **OK** (the process will take 1-2 minutes).



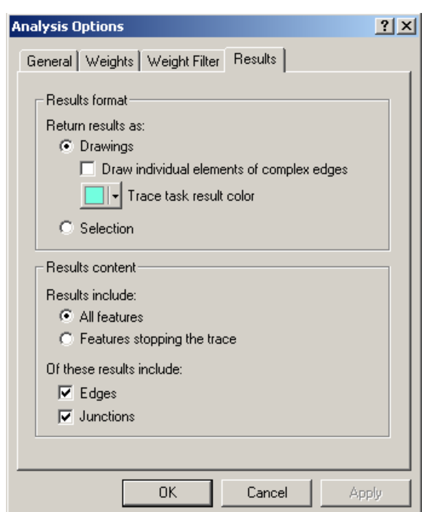
5.3.10 Trace Upstream to Select SnapControlPoints on Network

Objective: Do a "trace upstream" task to select SnapControlPoints on the stream network

- Using the **Utility Network Analyst** toolbar, place a **junction flag**  at the most downstream **SnapControlPoint** in the basin.

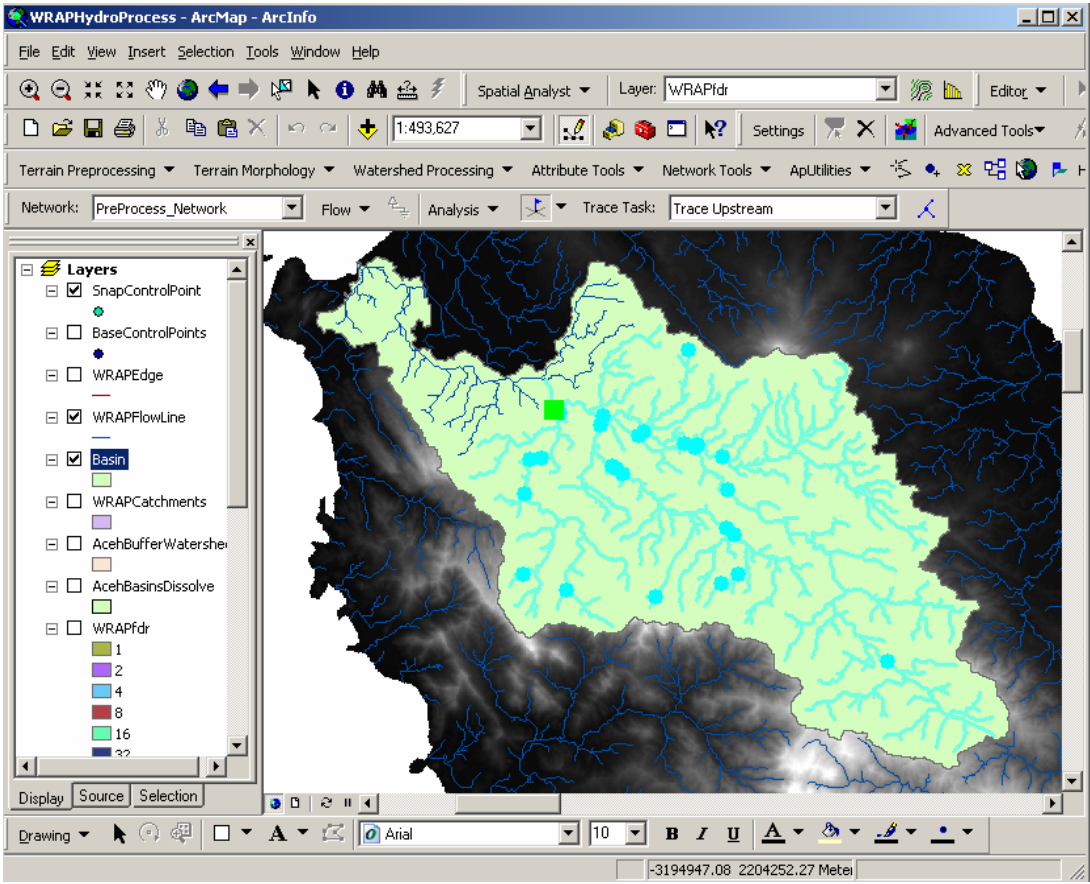


- In the **Analysis / Options** of the toolbar, click on the **Results** tab. Make sure the *Results format* of the trace will be returned as a **Drawing** and that *Results include* **All Features**. Click **Apply** and **OK**.



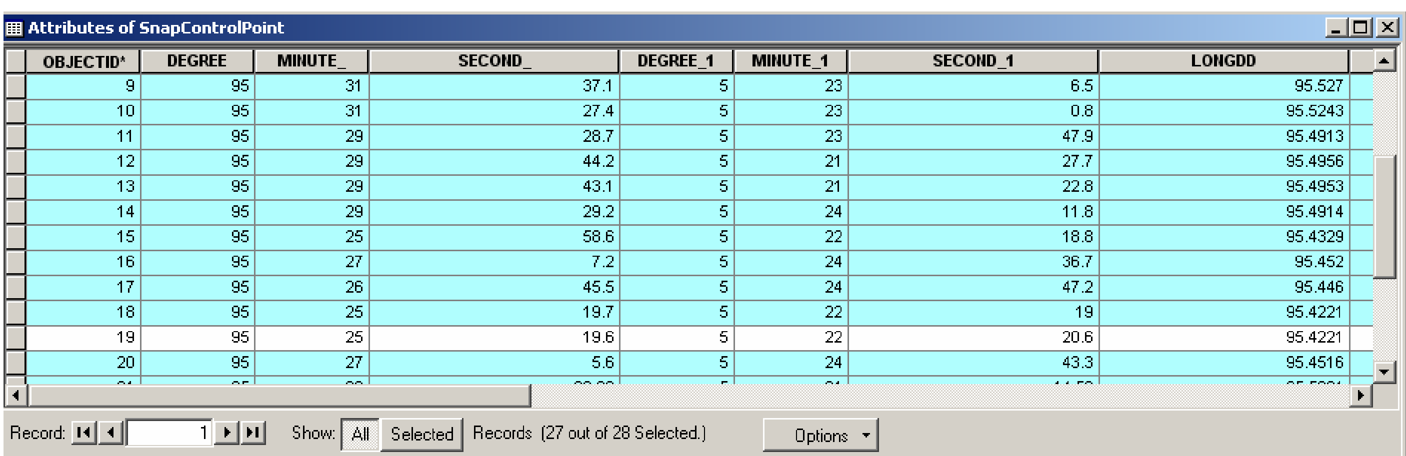
- Choose **Trace Task / Trace Upstream** 

. Click the **Solve** button  to perform the upstream trace.



All network features upstream of the most downstream control point of the Aceh Basin are selected.

- Open the attribute table for **SnapControlPoint**.



OBJECTID*	DEGREE	MINUTE_	SECOND_	DEGREE_1	MINUTE_1	SECOND_1	LONGDD
9	95	31	37.1	5	23	6.5	95.527
10	95	31	27.4	5	23	0.8	95.5243
11	95	29	28.7	5	23	47.9	95.4913
12	95	29	44.2	5	21	27.7	95.4956
13	95	29	43.1	5	21	22.8	95.4953
14	95	29	29.2	5	24	11.8	95.4914
15	95	25	58.6	5	22	18.8	95.4329
16	95	27	7.2	5	24	36.7	95.452
17	95	26	45.5	5	24	47.2	95.446
18	95	25	19.7	5	22	19	95.4221
19	95	25	19.6	5	22	20.6	95.4221
20	95	27	5.6	5	24	43.3	95.4516

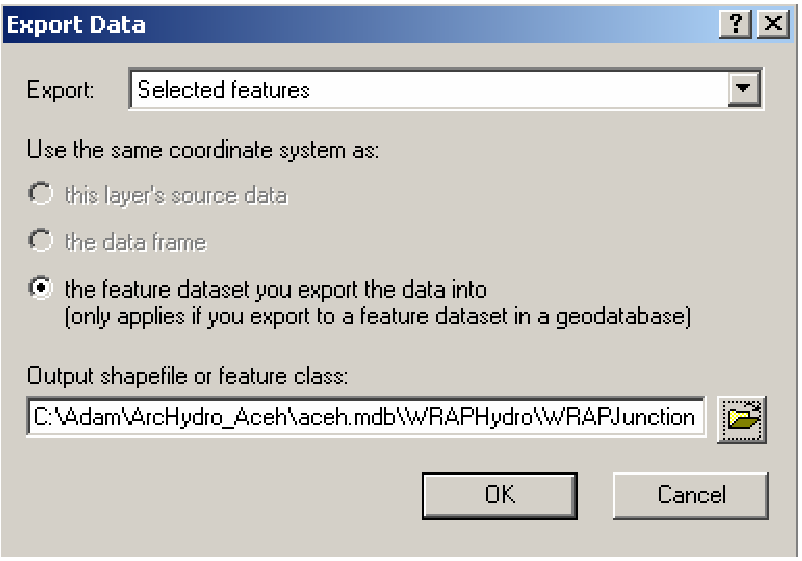
If not all **SnapControlPoints** are selected, then some SnapControlPoints are spatially coincident with each other. In other words, some of the points lie directly on top of each other. When this happens, only **one** of those points can participate in the geometric network. So, if three points are in the same location on the network, only one will be selected in the trace upstream task.

Only the SnapControlPoints that are participating in the network will be exported to the WRAPJunction feature class. This ensures that a clean geometric network is created to operate when calculating WRAP parameters.

5.3.11 Create a WRAPJunction feature class

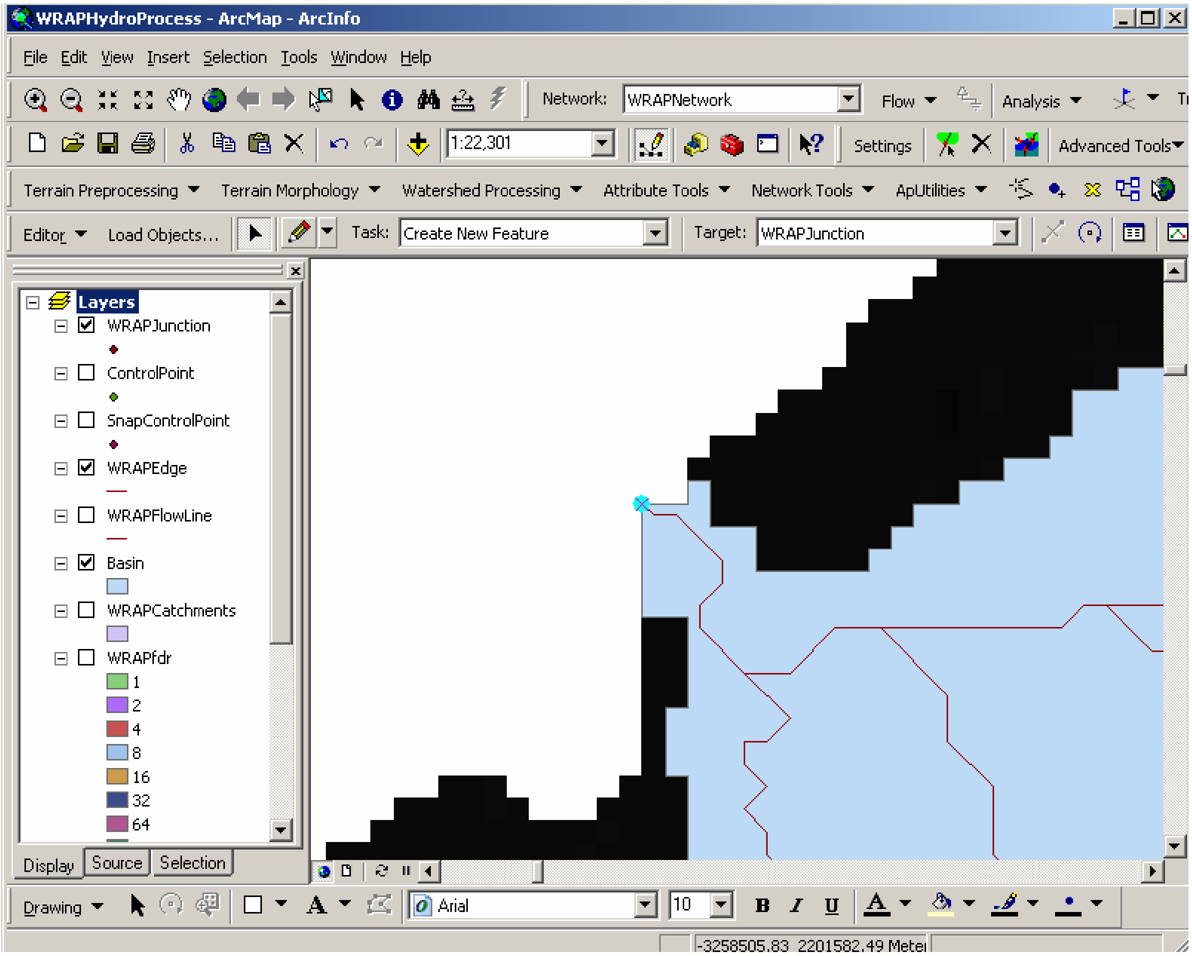
Objective: Create a new WRAPJunction feature class from the selected Snap Control Points and from the creation of an outlet point

- Right click on the **SnapControlPoint** feature class and go to **Export / Export Data**. Use the selected SnapControlPoints to create a new feature class in the **WRAPHydro** dataset. Call it **WRAPJunction**. Click **OK**.



- Start an edit session (**Editor / Start Editing**).

- In the **Editor Toolbar**, select **Create New Feature** as the *Task* and **WRAPJunction** as the *Target*. Use the **Sketch Tool** to place an outlet at the end of the Aceh River.



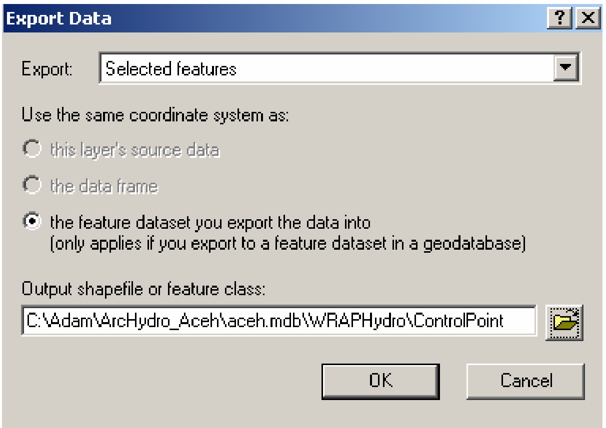
- Open the attribute table for the **WRAPJunction** feature class and locate the new point you have created (it should be at the bottom of the table). There will be no data in any of the fields except for the *ObjectID*. Give this new point the *Name* **Outlet** and fill in the next sequential number for the *WRAPCode* and *CRWRCode* (should be **29**). Close the attribute table.
- Repeat this process to add the outlet to the **SnapControlPoint** feature class or use **Load Objects** to copy the selected feature from **WRAPJunction** based off the **CRWRCode** for the outlet.
- Stop the edit session and save all edits.

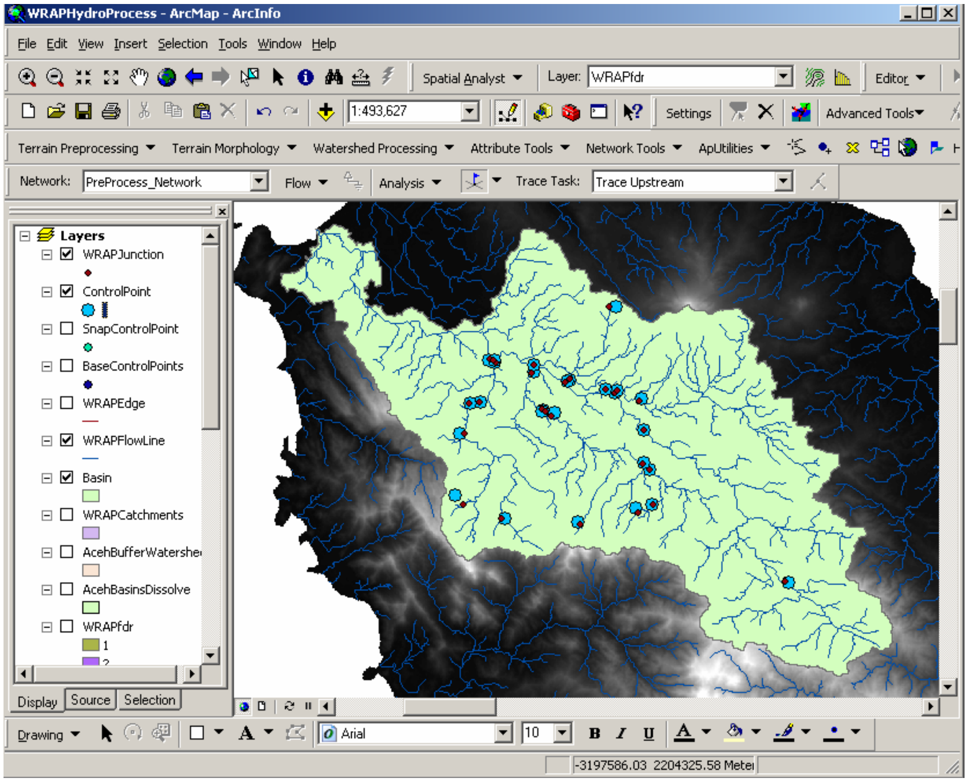
5.4 Finding Watershed Parameters

5.4.1 Export BaseControlPoint to ControlPoint

Objective: Export the BaseControlPoint file to WRAPHydro and call it ControlPoint.

- Open the attribute table for the **BaseControlPoint** feature class and highlight all rows. Right click on the feature class and select **Export / Export Data**. Create a new feature class in the **WRAPHydro** feature dataset, and call the new feature class **ControlPoint**. Click **OK**.





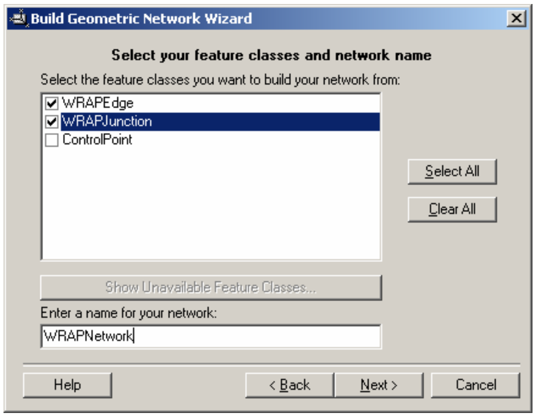
- Save changes and close **ArcMap**.

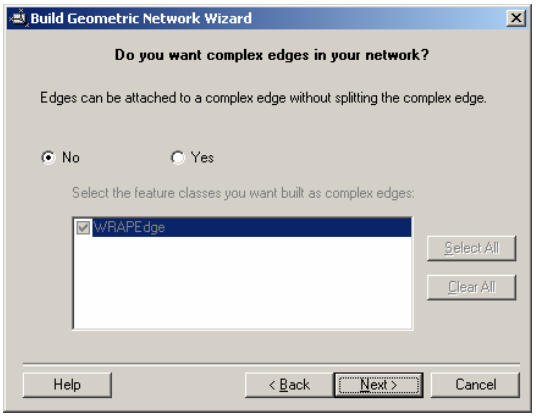
5.4.2 Build WRAPJunction and WRAPEdge Network

Objective: Build a network with WRAPJunction and WRAPEdge using WRAPEdge as a simple edge feature

A new network called WRAPNetwork is created using the WRAPEdge and WRAPJunction. This network is built with WRAPEdge as a simple edge feature. Once the network is built the flow directions are assigned to the network using the FlowDir attributes in WRAPEdge.

- Open **ArcCatalog**. Right click on the **WRAPHydro** feature dataset, and go to **New / Geometric Network**.
- Create a new geometric network with **WRAPJunction** and **WRAPEdge** as a simple edge feature and call the network **WRAPNetwork**. Accept the defaults for all other network creation options.

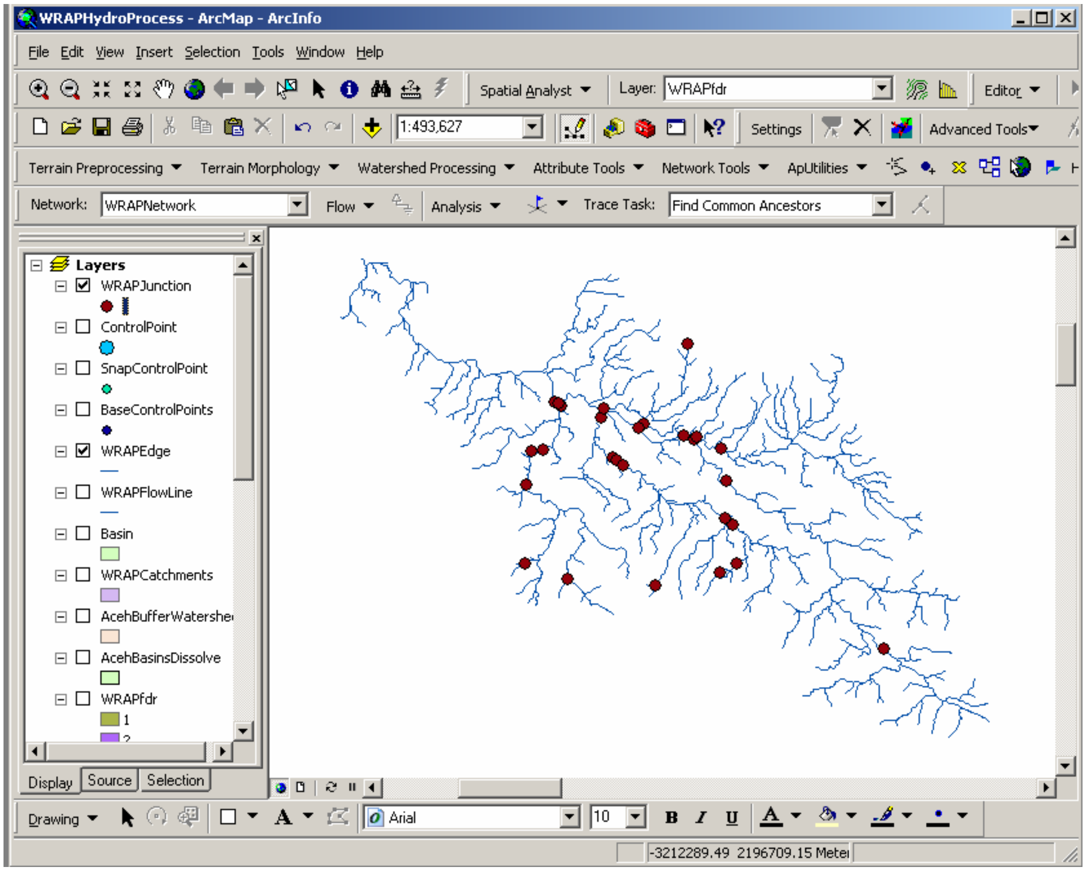




- The geometric network has been created (the WRAPNetwork icon should appear in the WRAPHydro feature dataset). Close **ArcCatalog**.

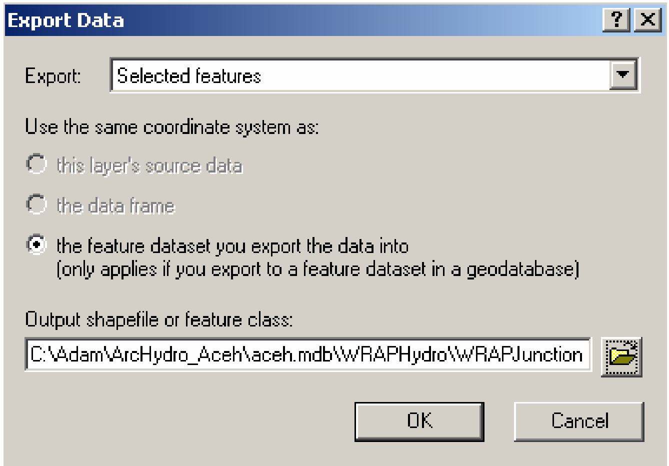
5.4.3 Make a copy of the WRAPJunction feature class

- Open the **WRAPHydroProcess** project in **ArcMap** and add **WRAPEdge** and **WRAPJunction** to the map if necessary.



We will use WRAPEdges as the outlet zones for watershed delineation. Each watershed will eventually be related to the downstream WRAPJunction that the WRAPEdge flows to. However, currently some WRAPJunctions lie within the middle of a WRAPEdge. By building the geometric network with simple edges instead of complex edges, the edges will be split when new junction features are loaded into the middle of them. Therefore, we will "reload" the WRAPJunctions, automatically splitting any edges with WRAPJunctions in the middle.

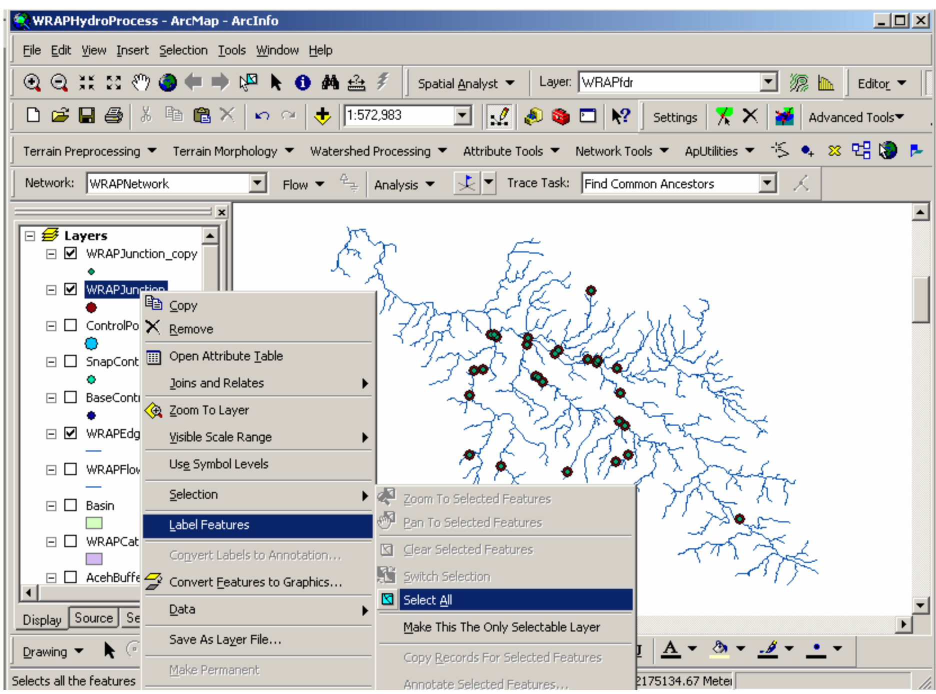
- Open the attribute table for the **WRAPJunction** feature class and highlight all rows. Right click on the feature class and select **Export / Export Data**. Create a new feature class in the **WRAPHydro** feature dataset and call the new feature class **WRAPJunction_copy**. Click **OK**.



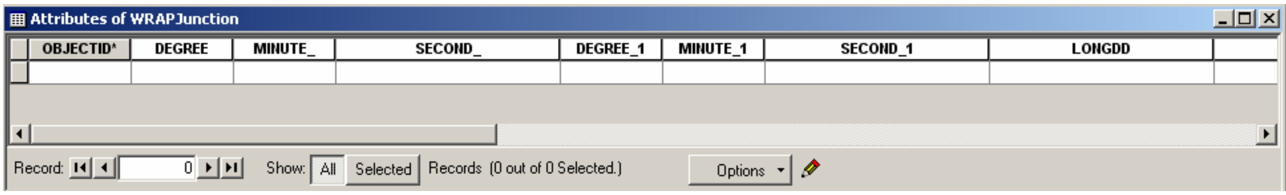
5.4.4 Delete WRAPJunction features and load back from 'copy'

Objective: Delete all the features from WRAPJunction and load the features back from the 'copy' file using the Load objects command

- Go to **Editor / Start Editing**.
- Right click on the **WRAPJunction** layer in the ArcMap table of contents. Click **Selection / Select All**.

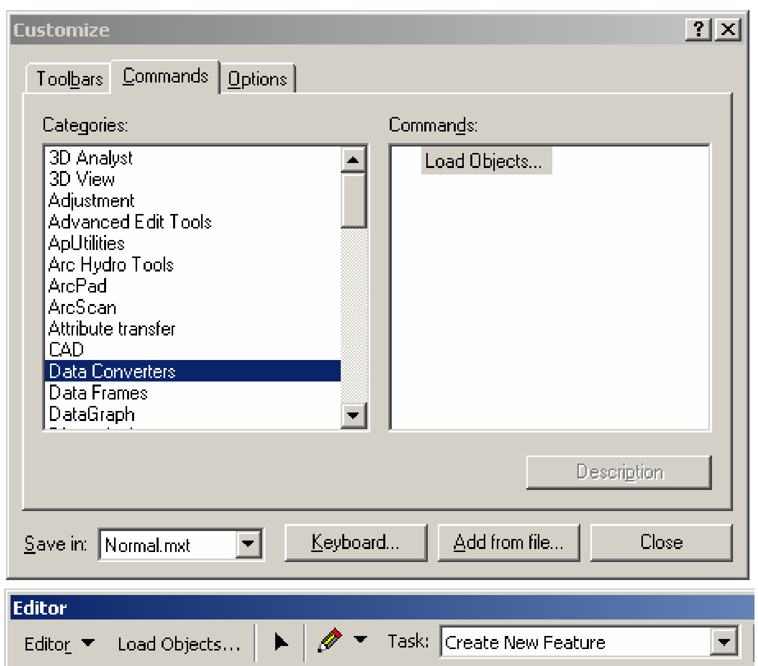


- Delete all selected features by going to the **Edit** menu (next to the File menu) and clicking **Delete**. All WRAPJunctions will be deleted.



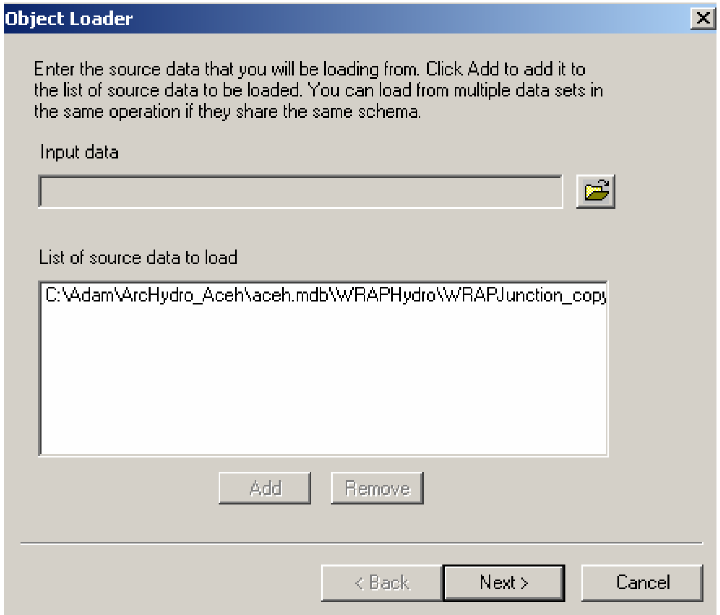
- Make sure the **WRAPJunction** feature class is the target in the **Editor** toolbar.

- The **Load Objects** button is a standard ArcGIS tool that is enabled when an edit session is open.
- If the **Load Objects** button does not appear on the screen, add it to the Editor toolbar by clicking **Tools** / **Customize**. Click the **Commands** tab and the **Data Converters** category. Drag the **Load Objects** command from the *Commands* side of the window to the **Editor Toolbar**.

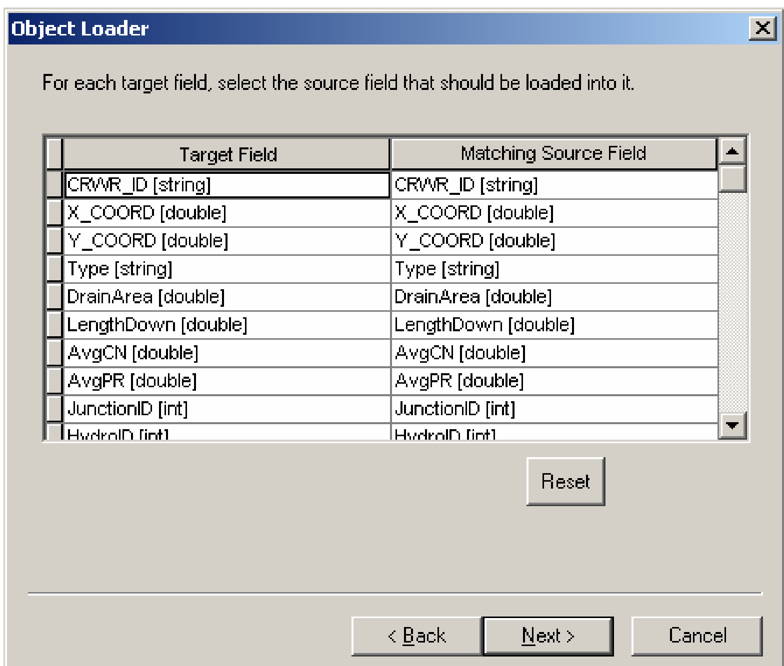


- Click the **Load Objects** button.
- Click the folder  button and browse to **WRAPJunction_Copy**. Click **Open**.

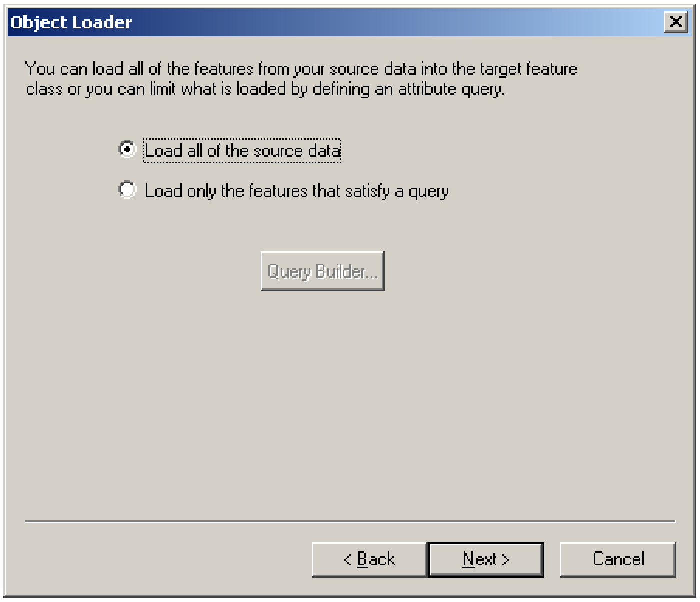
- Click **Add** to add this data source.



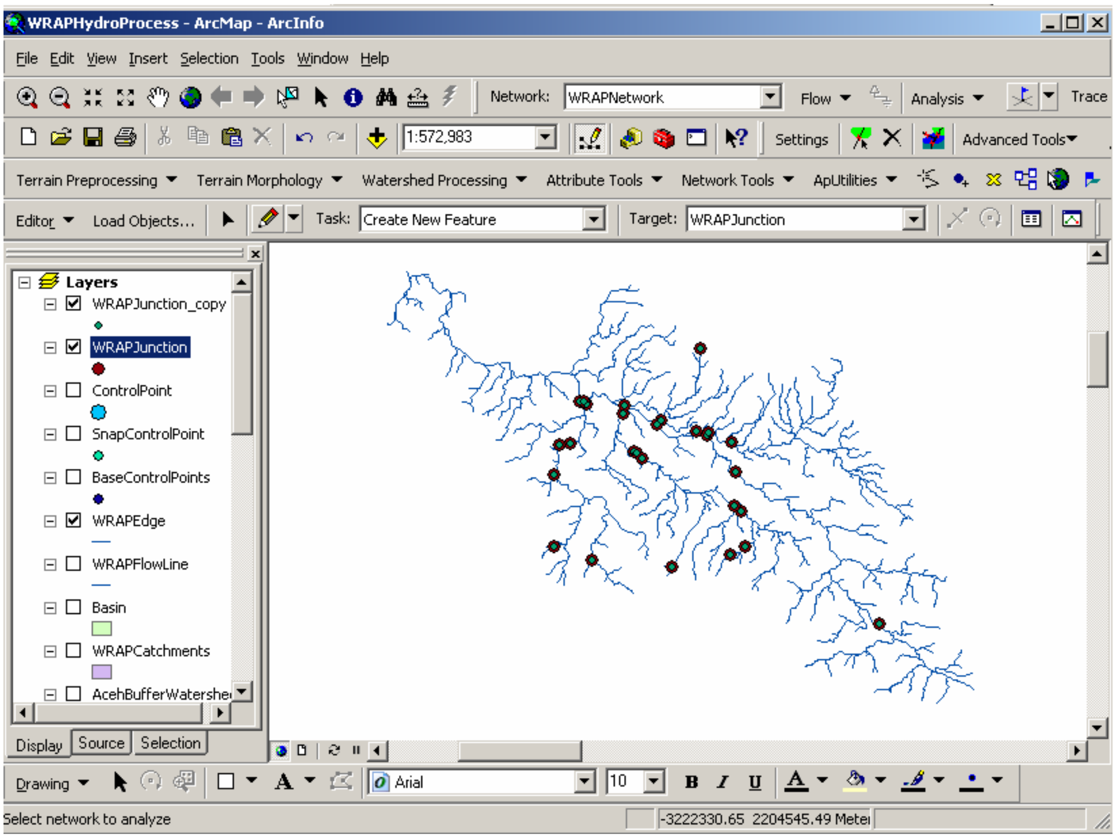
- Click **Next**.
- The **WRAPJunction** and **WRAPJunction_copy** have the same fields, so click **Next**.



- Choose to *load all of the source data*. Click **Next**.



- The data does **not** need to be snapped or validated, so click **Next** and then **Finish** on the last two slides to load the data. Now all junctions should be back!

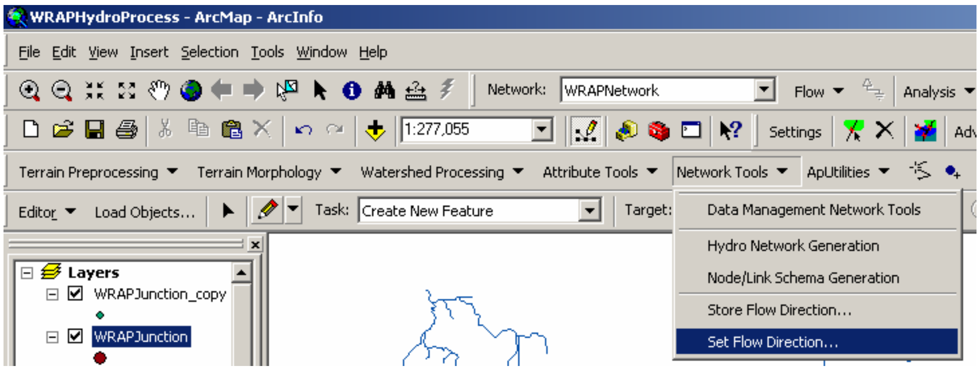


- Stop editing and save edits.

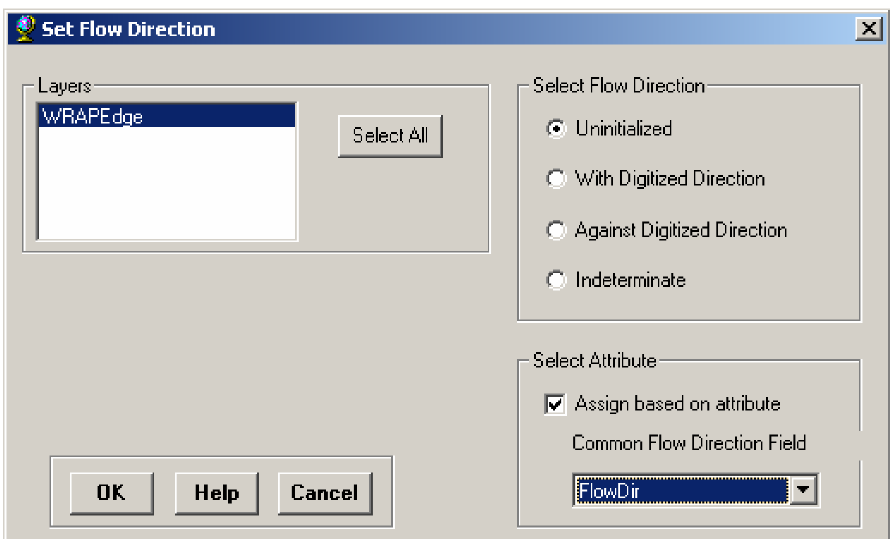
5.4.5 Set Flow Directions

Objective: Set the flow directions for WRAPEdges after loading the Junctions

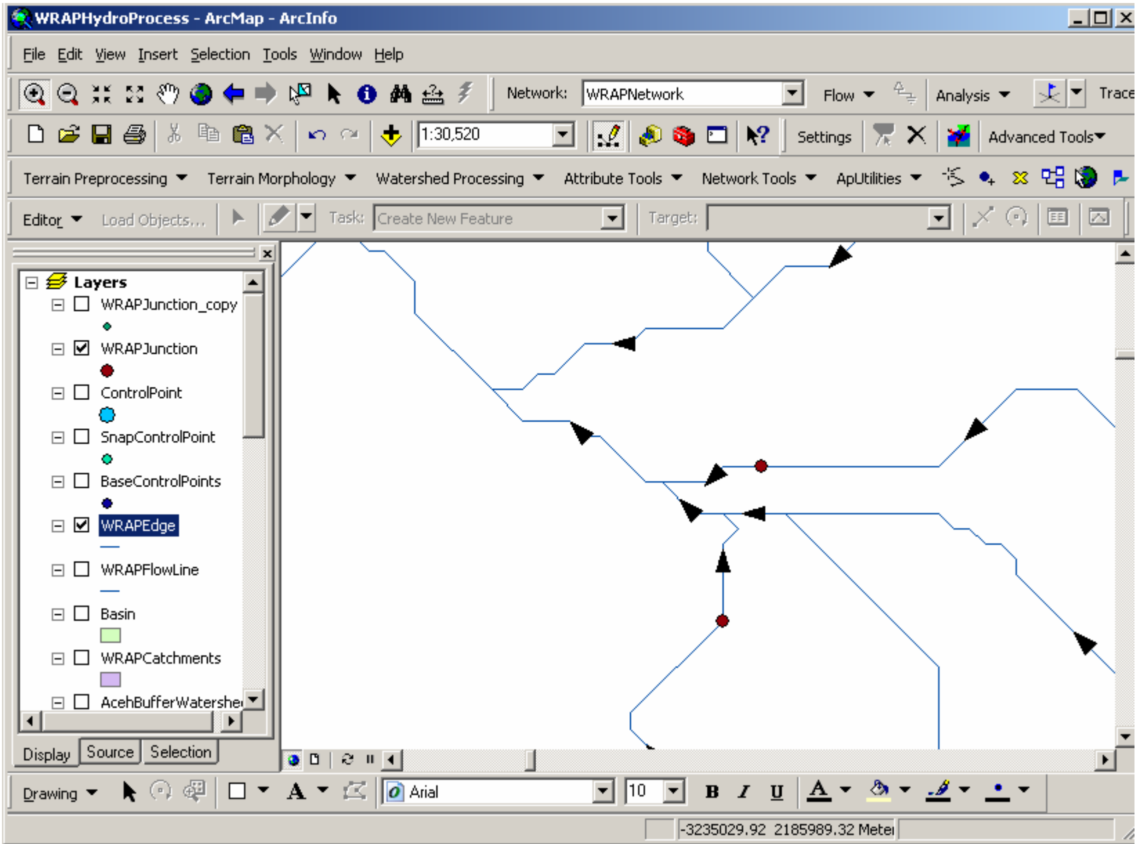
- Click on **Network Tools / Set Flow Direction** in the **ArcHydro** tools.



- Select the **WRAPEdge** as the input for the *Layers* field, leave the *Select Flow Direction* field as **Uninitialized**, and assign the flow direction based on the **FlowDir** attribute in the *Select Attribute* field. Click **OK** (the process will take 1-2 minutes).



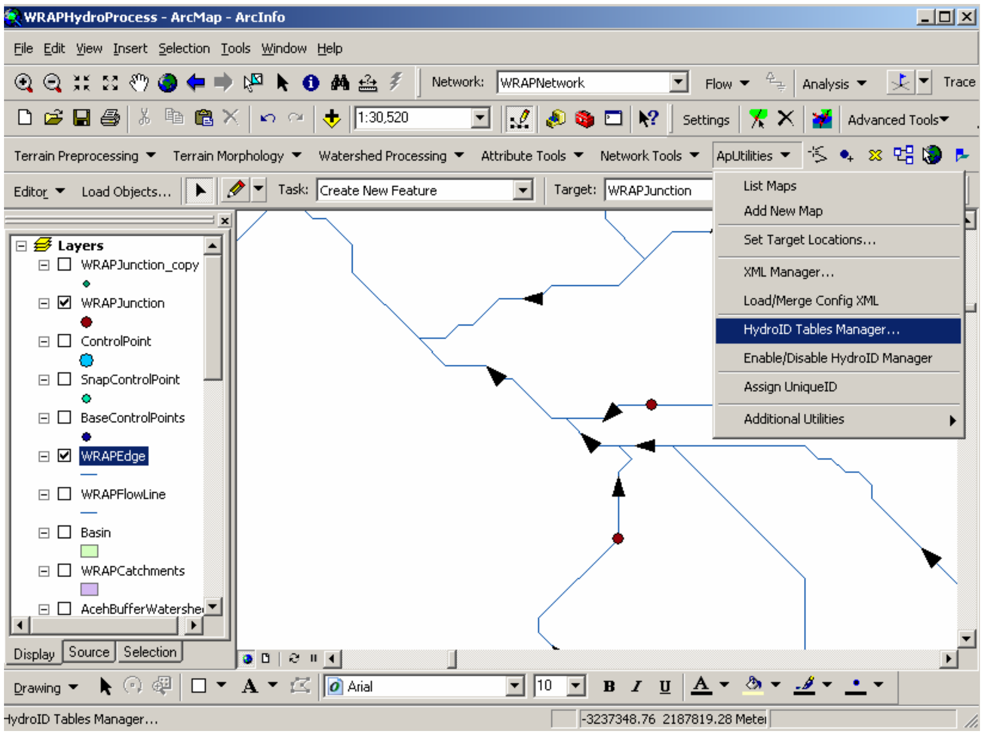
The result is:



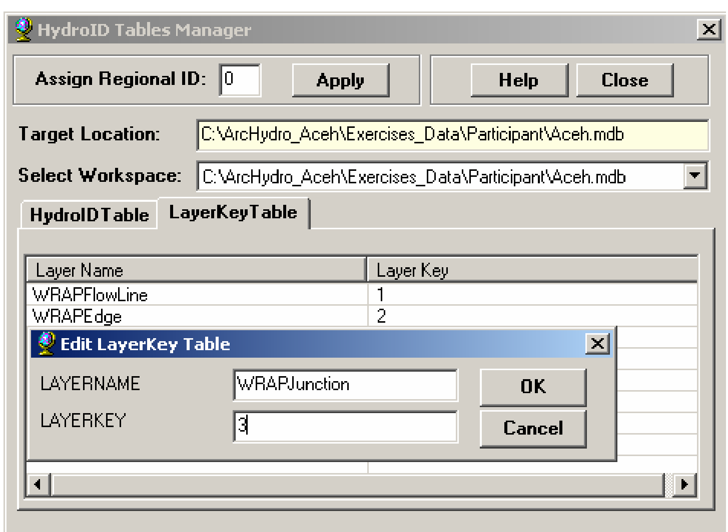
5.4.6 Set the HydroIDs for Junctions and Edges

Objective: Use HydroID tables manager to set the HydroID values for Junctions and Edges

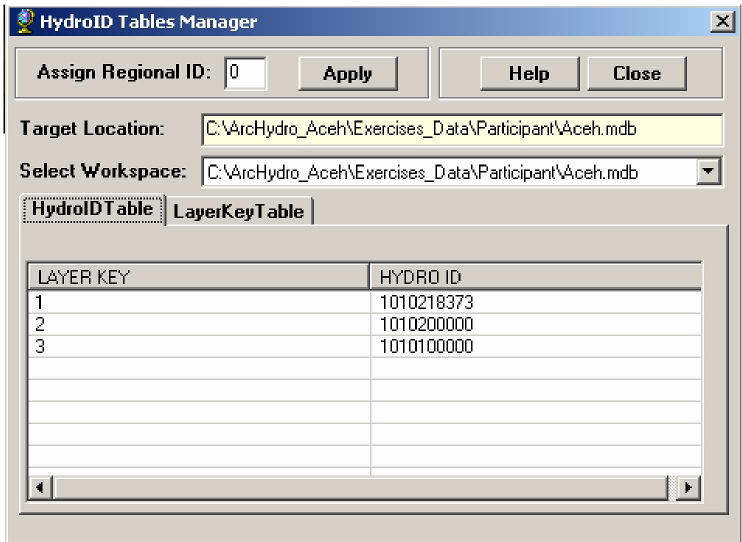
- Start an edit session (**Editor / Start Editing**).
- In the **ArcHydro** tools, open **ApUtilities / HyroID Tables Manager**.



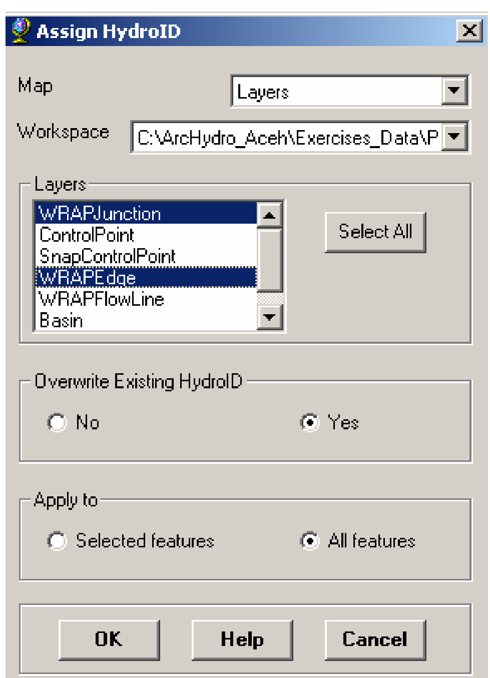
- Go to the *LayerKeyTable* tab and right click on the line below WRAPFlowLine to add the **WRAPEdge** and **WRAPJunction** feature classes as *Layer Key* numbers 2 and 3, respectively.



- Go to the *HydroID Table* tab and assign the **HydroID** for the keys 2 and 3. This HydroID will have 10 digits. The first one corresponds to the country (we will use “1” for Indonesia). The Aceh River is located in the Aceh basin, identified as the hydrological subregion number 01. The next two digits identify the type of geographic element. Number 01 will be assigned for the junctions (ControlPoint, WRAPJunctions), while number 02 is assigned for the edges (WRAPFlowLine, WRAPEdge). The last five digits will describe the feature number (entered initially as all zeroes). Click **Close**.



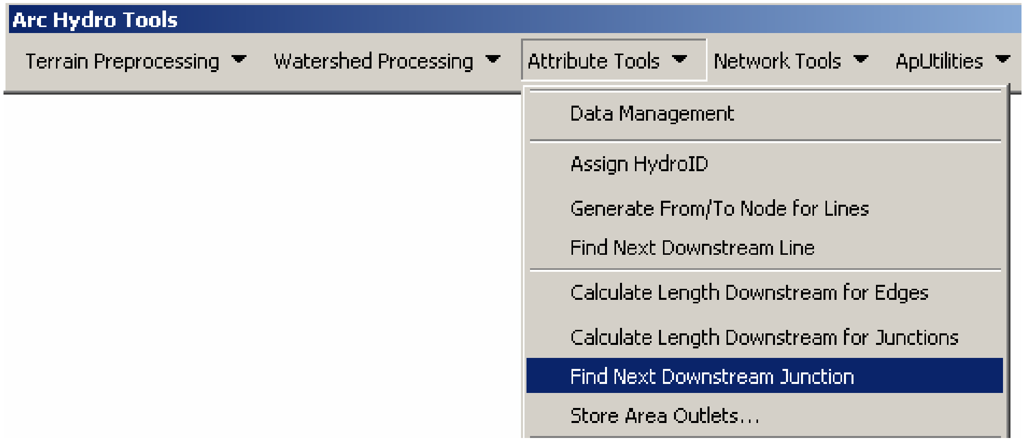
- In the **ArcHydro** tools, open **Attribute Tools / Assign HydroID**.
- Highlight the layers **WRAPJunction** and **WRAPEdge** in the *Layers* box and select **Yes** to *Overwrite existing HydroID*. Apply it to **All features** and click **OK**.



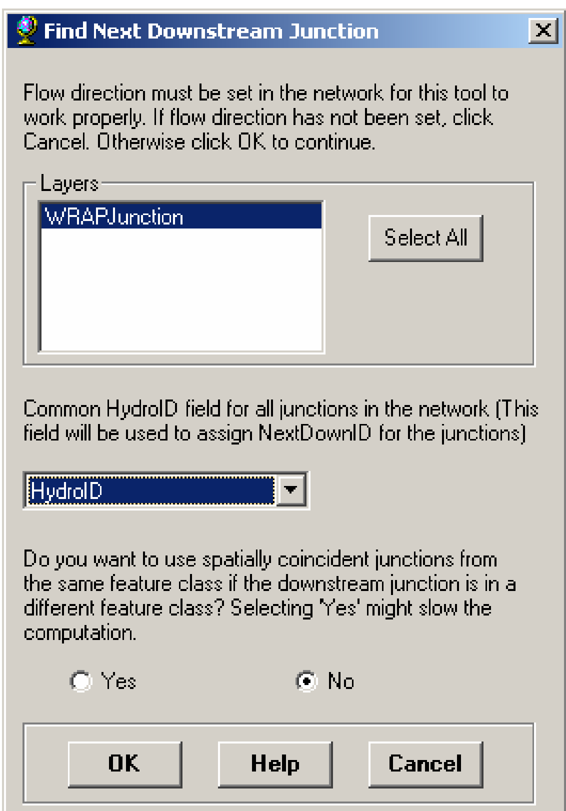
5.4.7 Determine NextDownID

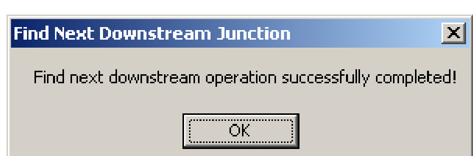
Objective: Determine the Next Downstream ID for every WRAPJunction

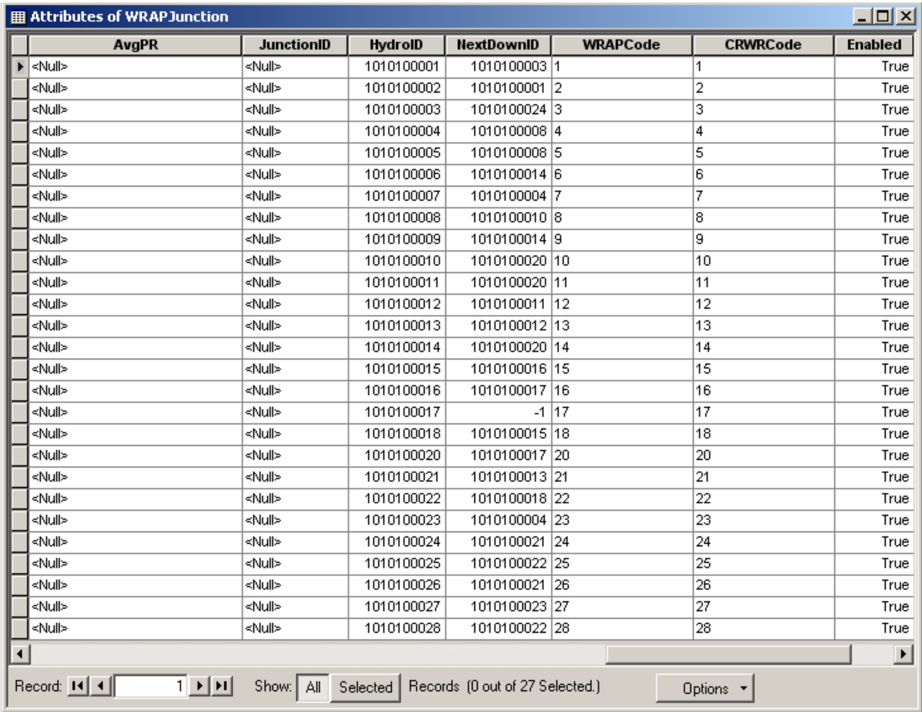
- In the **ArcHydro** tools, open **Attribute Tools / Find Next Downstream Junction**.



- Select **WRAPJunction** in the *Layers* box as the HydroJunction input and the **HydroID** as the common field for all junctions in the network. This field will be used to assign NextDownID for the junctions. Select **No** for spatially coincident junctions and click **OK**.





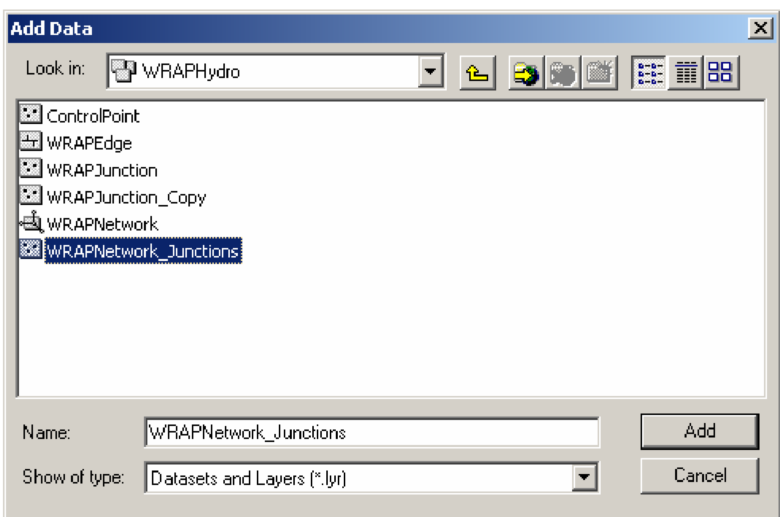


Attributes of WRAPJunction

AvgPR	JunctionID	HydroID	NextDownID	WRAPCode	CRWRCode	Enabled
<Null>	<Null>	1010100001	1010100003	1	1	True
<Null>	<Null>	1010100002	1010100001	2	2	True
<Null>	<Null>	1010100003	1010100024	3	3	True
<Null>	<Null>	1010100004	1010100008	4	4	True
<Null>	<Null>	1010100005	1010100008	5	5	True
<Null>	<Null>	1010100006	1010100014	6	6	True
<Null>	<Null>	1010100007	1010100004	7	7	True
<Null>	<Null>	1010100008	1010100010	8	8	True
<Null>	<Null>	1010100009	1010100014	9	9	True
<Null>	<Null>	1010100010	1010100020	10	10	True
<Null>	<Null>	1010100011	1010100020	11	11	True
<Null>	<Null>	1010100012	1010100011	12	12	True
<Null>	<Null>	1010100013	1010100012	13	13	True
<Null>	<Null>	1010100014	1010100020	14	14	True
<Null>	<Null>	1010100015	1010100016	15	15	True
<Null>	<Null>	1010100016	1010100017	16	16	True
<Null>	<Null>	1010100017	-1	17	17	True
<Null>	<Null>	1010100018	1010100015	18	18	True
<Null>	<Null>	1010100020	1010100017	20	20	True
<Null>	<Null>	1010100021	1010100013	21	21	True
<Null>	<Null>	1010100022	1010100018	22	22	True
<Null>	<Null>	1010100023	1010100004	23	23	True
<Null>	<Null>	1010100024	1010100021	24	24	True
<Null>	<Null>	1010100025	1010100022	25	25	True
<Null>	<Null>	1010100026	1010100021	26	26	True
<Null>	<Null>	1010100027	1010100023	27	27	True
<Null>	<Null>	1010100028	1010100022	28	28	True

Record: 1 Show: All Selected Records (0 out of 27 Selected.) Options

- If the HydroID option does not appear as the common field, add the **WRAPNetwork_Junctions** feature class from the **WRAPHydro** feature dataset to your ArcMap document.

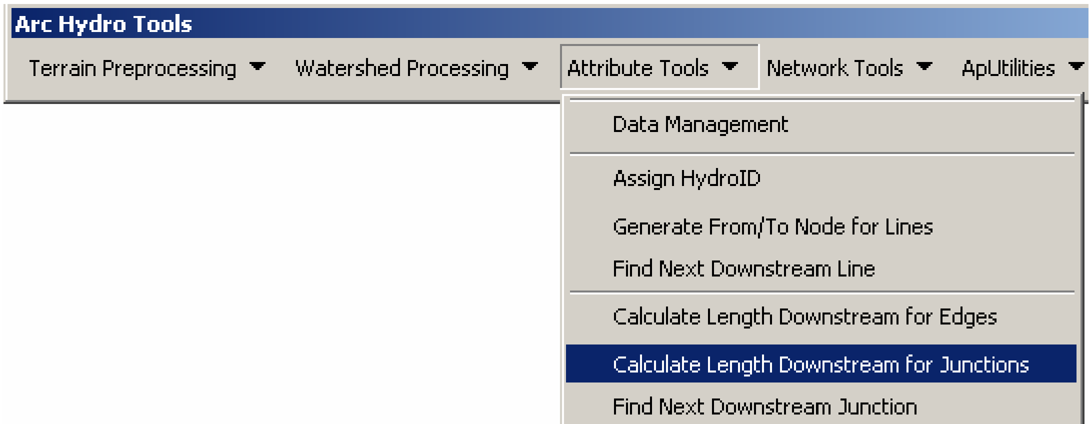


- Assign **HydroIDs** for the **WRAPNetwork_Junctions** feature class. Do not worry about the regional HydroIDs for this step (all we need is to have the HydroID column in the attribute table).
- Remove the **WRAPNetwork_Junctions** feature class from your document and try again to calculate the **NextDownID** for the **WRAPJunctions**.
- The **NextDownID** field of the WRAPJunction attribute table has been populated. This value points to the HydroID of the NextDownID in the stream network.

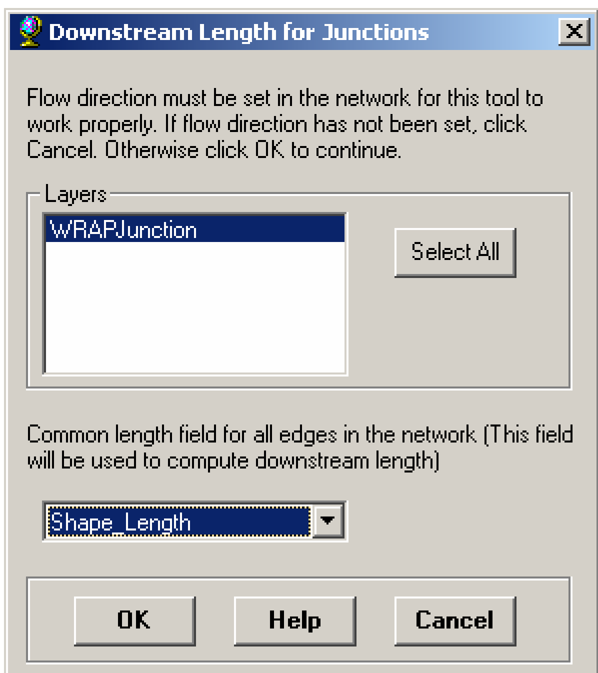
5.4.8 Calculate LengthDown

Objective: Calculate the length to outlet of every WRAPJunction

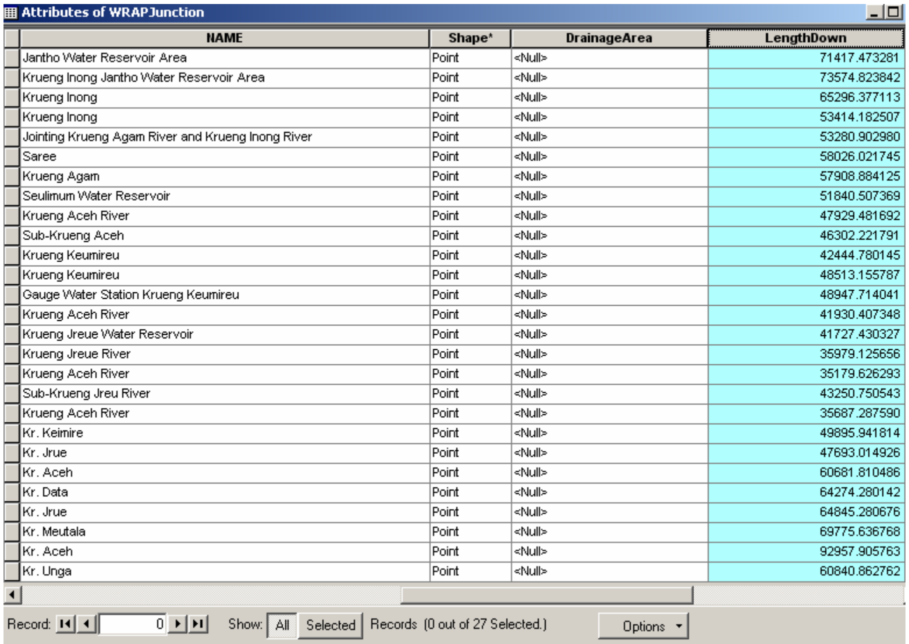
- In the ArcHydro toolset, select **Attribute Tools / Calculate Length Downstream for Junctions**.



- Choose **WRAPJunction** as the HydroJunction. Select the **Shape_Length** field for WRAPEdge. Click **OK**.



- The **LengthDown** field of the WRAPJunction attribute table has been populated with the distance (in meters) to the outlet of the stream network.


Attributes of WRAPJunction

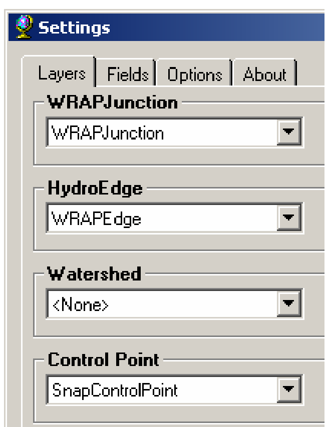
NAME	Shape*	DrainageArea	LengthDown
Jantho Water Reservoir Area	Point	<Null>	71417.473281
Krueng Inong Jantho Water Reservoir Area	Point	<Null>	73574.823842
Krueng Inong	Point	<Null>	65296.377113
Krueng Inong	Point	<Null>	53414.182507
Jointing Krueng Agam River and Krueng Inong River	Point	<Null>	53280.902980
Saree	Point	<Null>	58026.021745
Krueng Agam	Point	<Null>	57908.884125
Seulimum Water Reservoir	Point	<Null>	51840.507369
Krueng Aceh River	Point	<Null>	47929.481692
Sub-Krueng Aceh	Point	<Null>	46302.221791
Krueng Keumireu	Point	<Null>	42444.780145
Krueng Keumireu	Point	<Null>	48513.155787
Gauge Water Station Krueng Keumireu	Point	<Null>	48947.714041
Krueng Aceh River	Point	<Null>	41930.407348
Krueng Jreue Water Reservoir	Point	<Null>	41727.430327
Krueng Jreue River	Point	<Null>	35979.125656
Krueng Aceh River	Point	<Null>	35179.626293
Sub-Krueng Jreu River	Point	<Null>	43250.750543
Krueng Aceh River	Point	<Null>	35687.287590
Kr. Keimire	Point	<Null>	49895.941814
Kr. Jrue	Point	<Null>	47693.014926
Kr. Aceh	Point	<Null>	60681.810486
Kr. Data	Point	<Null>	64274.280142
Kr. Jrue	Point	<Null>	64845.280676
Kr. Meutala	Point	<Null>	69775.636768
Kr. Aceh	Point	<Null>	92957.905763
Kr. Unga	Point	<Null>	60840.862762

Record: 0 Show: All Selected Records (0 out of 27 Selected.) Options

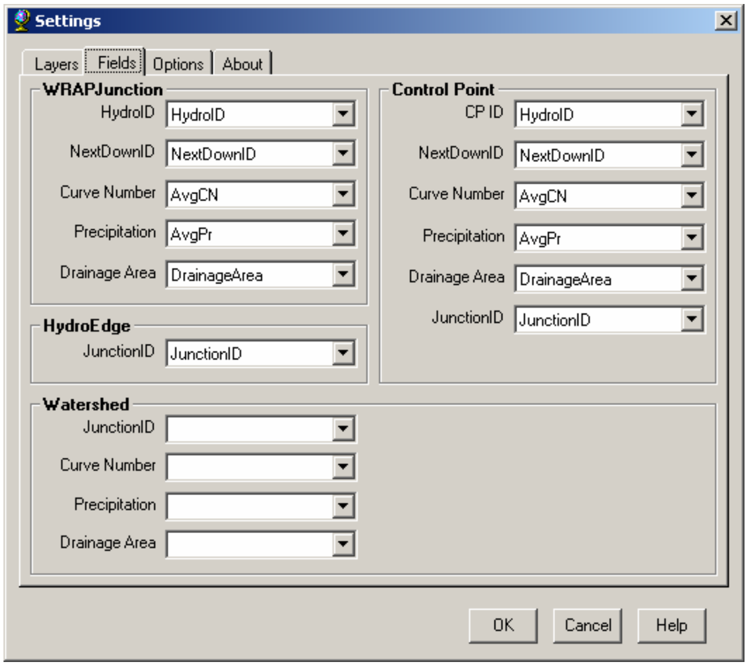
5.4.9 Assign JunctionIDs

Objective: Assign JunctionIDs to WRAPEdge

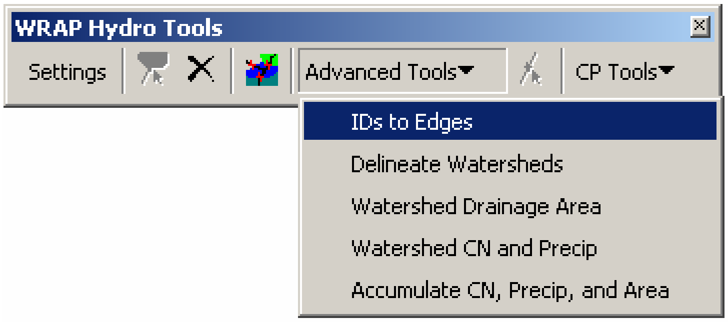
- Open the **WRAPEdge** attribute table and add the field **JunctionID** (long integer).
- Close the attribute table and go to **WRAPHydro Tools / Settings**.
- Click the **Layers** tab and select **WRAPJunction** (WRAPJunction layer), **WRAPEdge** (HydroEdge layer), **None** (Watershed layer) and **SnapControlPoint** (Control Point layer).



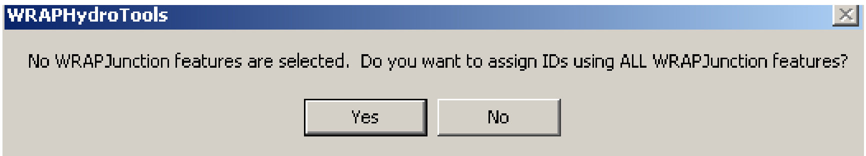
- Click the **Fields** tab. For the **WRAPJunction** fields, select **HydroID** (for HydroID), **NextDownID** (for NextDownID), **AvgCN** (for Curve Number), **AvgPr** (for Precipitation), and **DrainageArea** (for DrainageArea).
- For the **Control Point fields**, select **HydroID** (for CP ID) and **JunctionID** (for JunctionID). Use the same names for the remaining fields as for the WRAPJunction layer.
- For the **HydroEdge** field, select **JunctionID** (for JunctionID). Click **OK**.



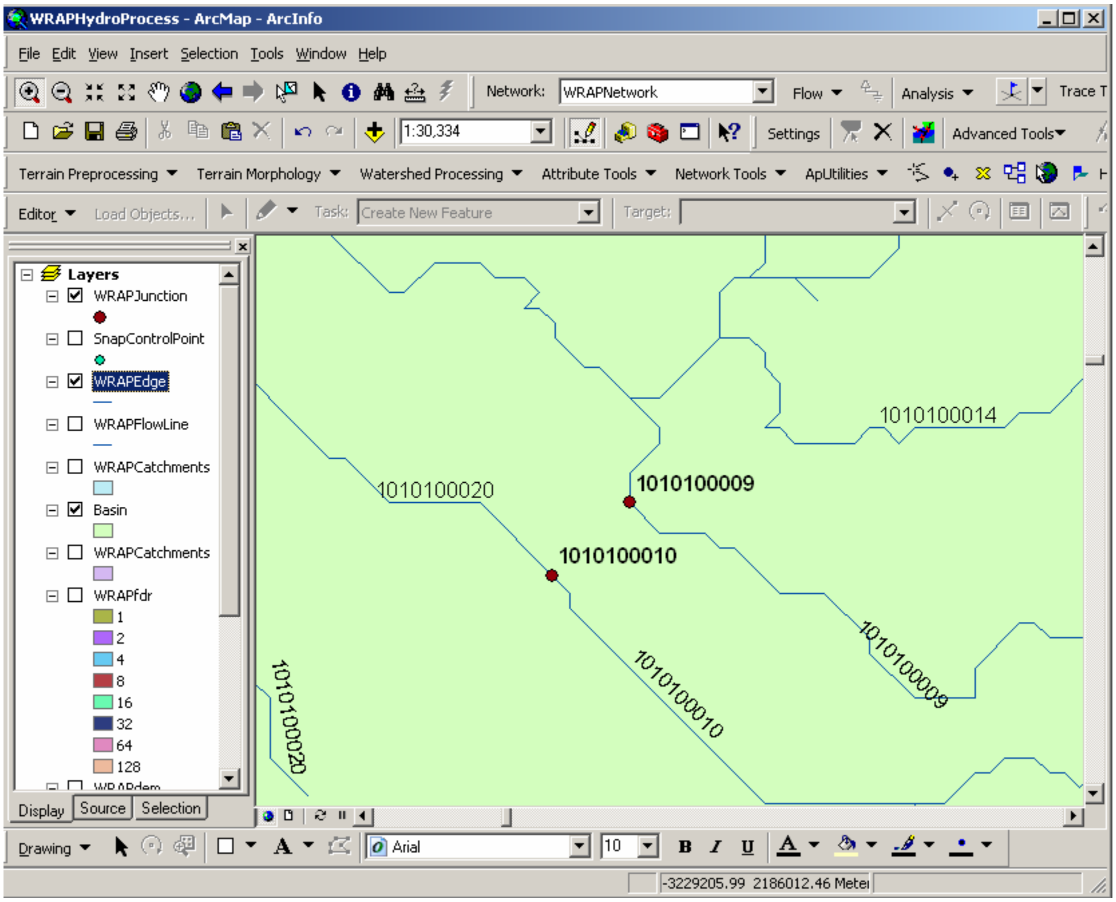
- Make sure no features are selected.
- In the WRAPHydro tools, select **Advanced Tools / IDs to Edges**.



- Click **OK** when given the reminder that flow direction must be set.
- Click **Yes** to assign IDs for all features.



All of the edges between two junctions now have the same JunctionID (which is the HydroID of the downstream junction).

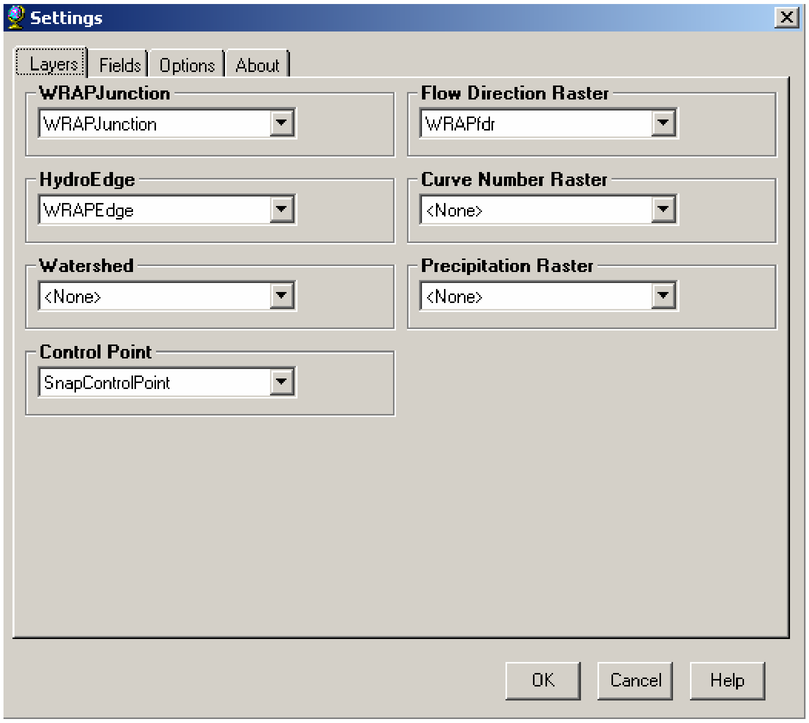


5.4.10 Delineate the upstream area for each WRAPJunction

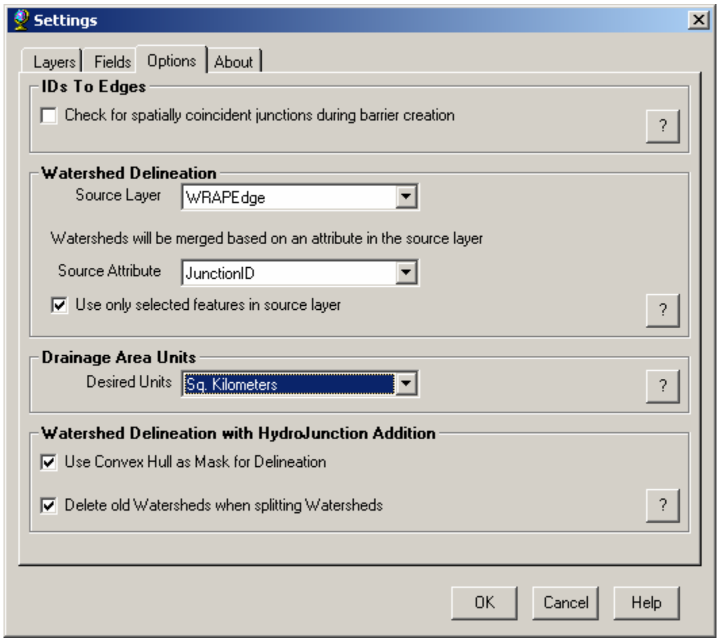
Objective: Delineate the upstream area for each WRAPJunction using WRAPEdge and WRAPfdr

Once all the JunctionIDs are populated, the **Delineate Watersheds Tool** in the WRAPHydro toolset is used to delineate watersheds for each junction. The watersheds are delineated using the WRAPFdr flow direction grid and the WRAPEdges as the outlet zones. The output is called **WRAPWatershed**. For each value of JunctionID of the edges, a watershed is created. Thus, a watershed is created for each Junction, since all the edges between two junctions have the same JunctionIDs. The DrainID field in the WRAPWatershed is populated with the JunctionID value of the Edges it drains to. Thus, each WRAPWatershed is already attributed with the HydroID of its outlet junction.

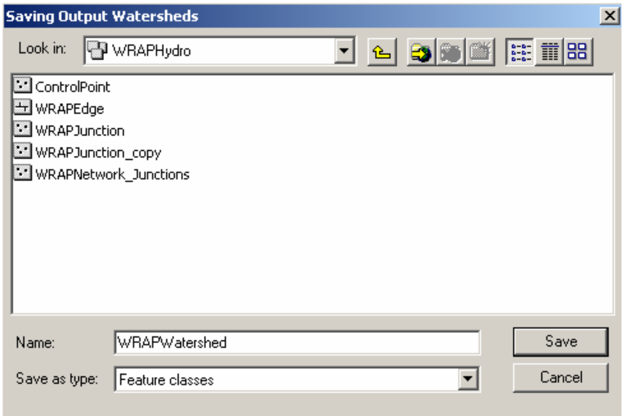
- Go to **WRAPHydro Tools** / **Settings**.
- Click the **Layers** tab and select **WRAPfdr** for the *Flow Direction Raster* field. Leave the *Curve Number Raster* and *Precipitation Raster* fields as **None**.

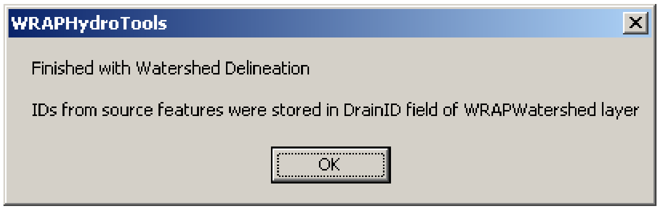


- Click the **Options** tab.
- In the **Watershed Delineation** section, select **WRAPEdge** as the *Source Layer* and **JunctionID** as the *Source Attribute*. Select **Square Kilometers** as the *Desired Units* in the **Drainage Area Units** section. Click **OK**.

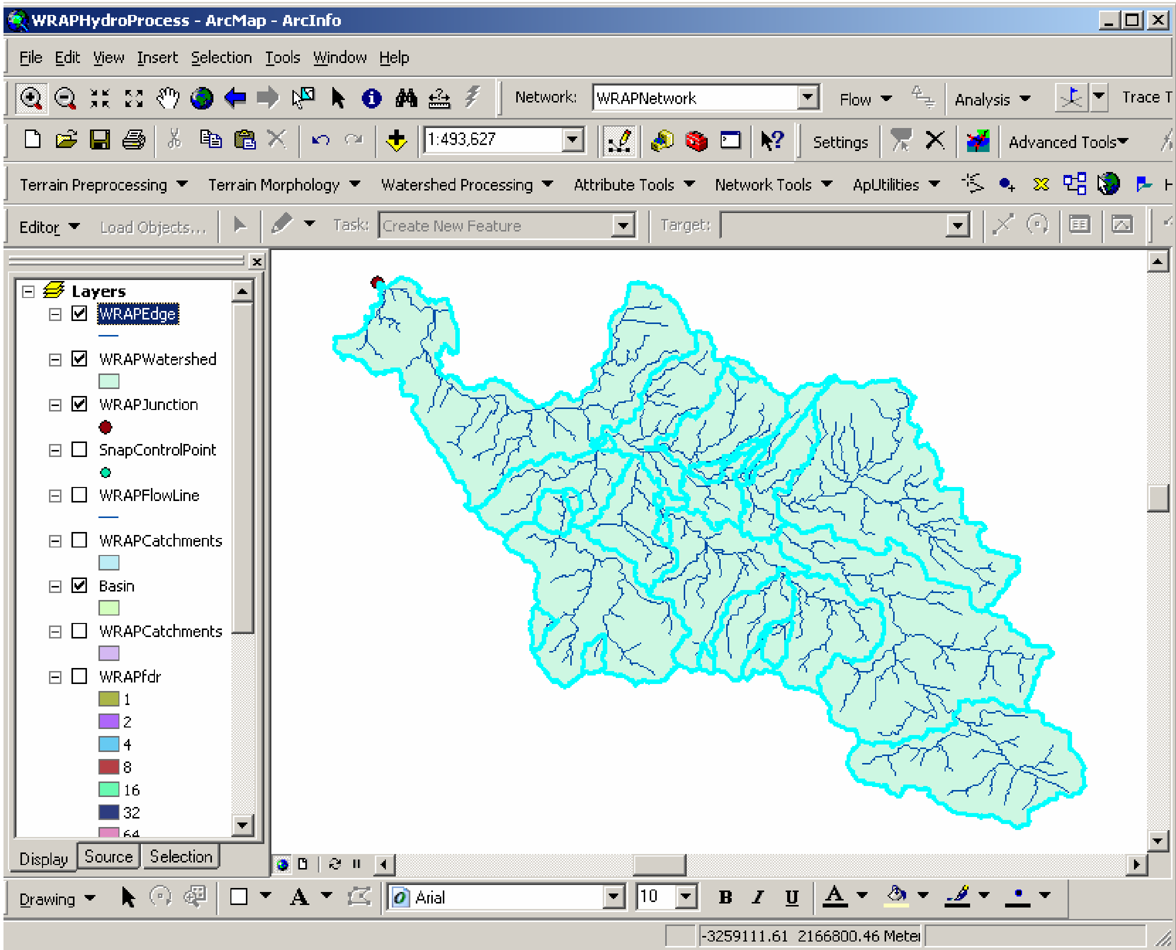


- In the **WRAPHydro** toolset, go to **Advanced Tools / Delineate Watersheds**.
- Save the output watersheds as **WRAPWatershed** in the **WRAPHydro** feature dataset.





One **WRAPWatershed** has now been delineated for each **WRAPJunction**.

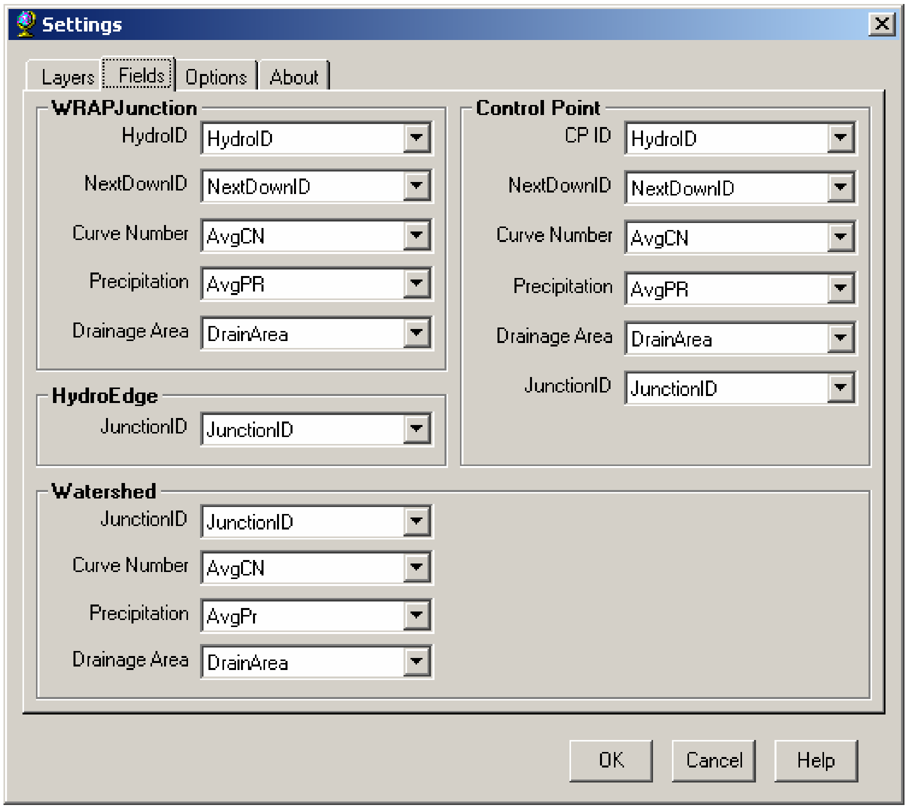


5.4.11 Calculate the Area, CN and Precip for each WRAPWatershed

Objective: Calculate the Watershed Drainage Area, Average Curve Number and Average precipitation for each WRAPWatershed

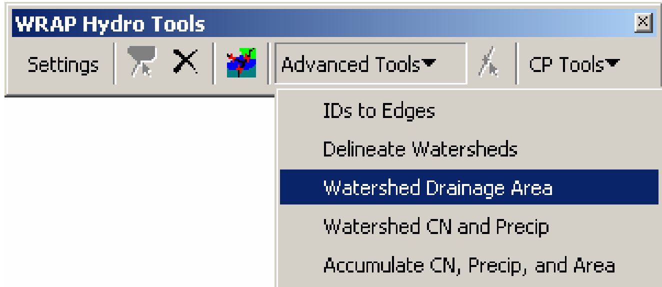
These values are populated in the **DrainArea**, AvgCN and AvgPR fields in the WRAPWatershed feature. The average value of Curve Number and Annual Precipitation for each Watershed is the mean of all the cell values within that area.

- Go to **WRAPHydro Tools / Settings**.
- Click the **Layers** tab and make sure that **WRAPWatershed** appears as the *Watershed* layer.
- Click the **Fields** tab and make sure that all of the fields for **Watershed** are filled in.

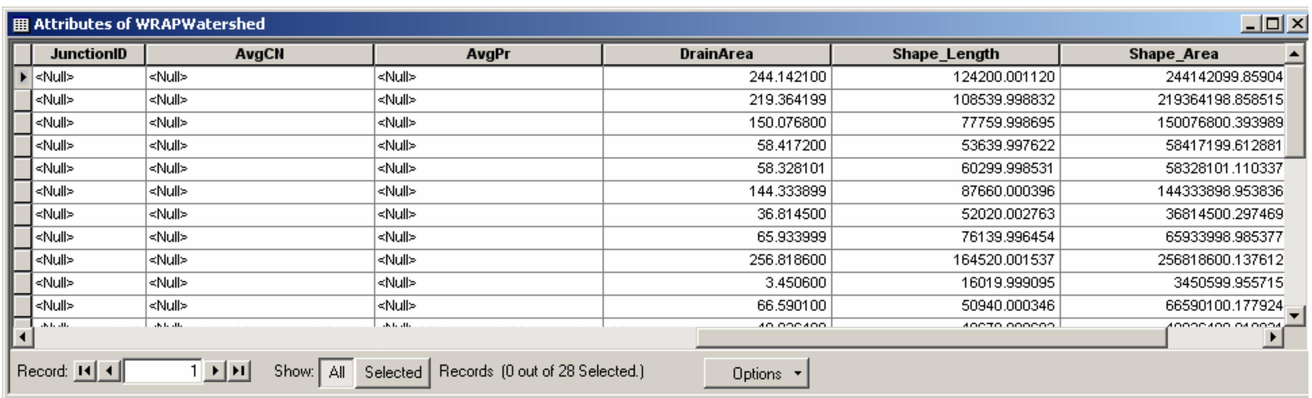


- Click the **Options** tab and verify that the *Drainage Area Units* are in **Square Kilometers**. Click **OK** to close the Settings form.

* In the WRAPHydro toolset, select **Advanced Tools** / **Watershed Drainage Area**. This procedure calculates the drainage area for each WRAPWatershed.



The **DrainArea** field of the **WRAPWatershed** feature class has been populated.

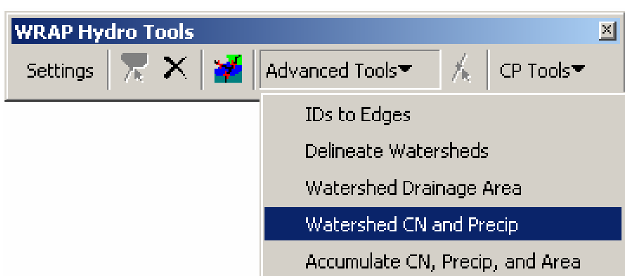


Attributes of WRAPWatershed

JunctionID	AvgCN	AvgPr	DrainArea	Shape_Length	Shape_Area
<Null>	<Null>	<Null>	244.142100	124200.001120	244142099.85904
<Null>	<Null>	<Null>	219.364199	108539.998832	219364198.858515
<Null>	<Null>	<Null>	150.076800	77759.998695	150076800.393989
<Null>	<Null>	<Null>	58.417200	53639.997622	58417199.612881
<Null>	<Null>	<Null>	58.328101	60299.998531	58328101.110337
<Null>	<Null>	<Null>	144.333899	87660.000396	144333898.953836
<Null>	<Null>	<Null>	36.814500	52020.002763	36814500.297469
<Null>	<Null>	<Null>	65.933999	76139.996454	65933998.985377
<Null>	<Null>	<Null>	256.818600	164520.001537	256818600.137612
<Null>	<Null>	<Null>	3.450600	16019.999095	3450599.955715
<Null>	<Null>	<Null>	66.590100	50940.000346	66590100.177924

Record: 1 Show: All Selected Records (0 out of 28 Selected.) Options

* In the WRAPHydro toolset, select **Advanced Tools** / **Watershed CN and Precip** (***only applies if you have those rasters***).

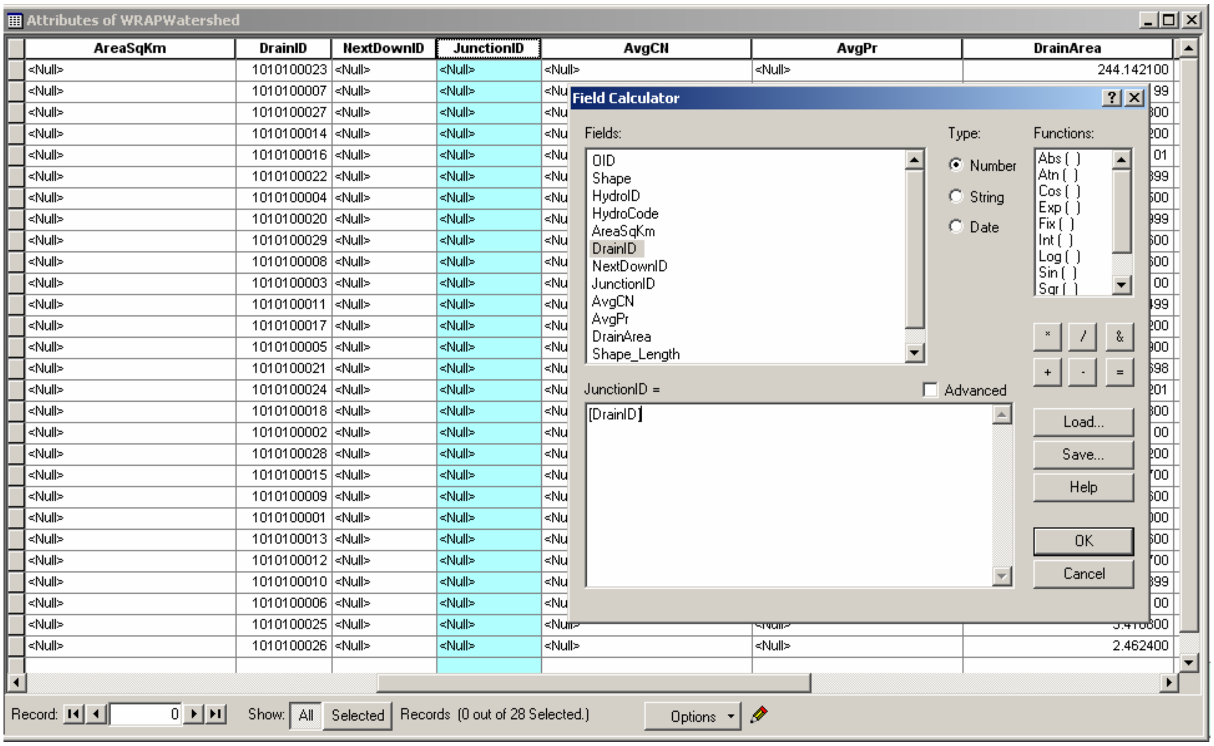


The **AvgCN** and **AvgPR** fields of the **WRAPWatershed** feature class have been populated.

5.4.12 Consolidate Area, Curve Number, and Precip for each WRAPJunction

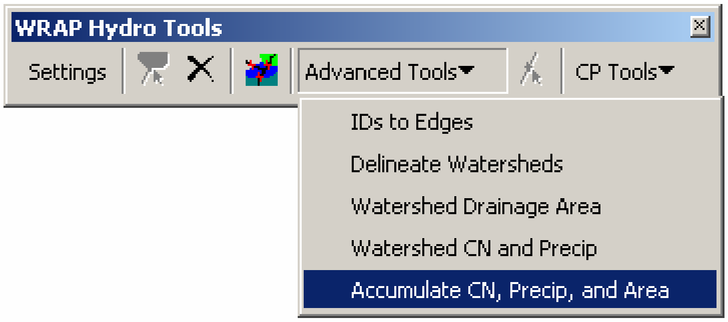
Objective: Consolidate the Watershed Drain Area, Average Curve Number, and Average Precipitation for each WRAPJunction

- Copy the **DrainID** values to the **JunctionID** field in the **WRAPWatershed** feature class using the field calculator.

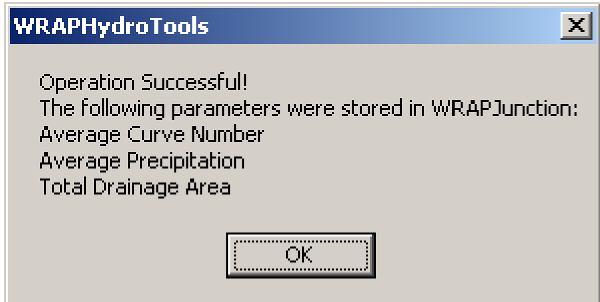


Once the incremental values for the drain area, curve number and annual precipitation have been determined for each feature in WRAPWatershed, these values are consolidated to add in the effects of all the area that is upstream of each junction.

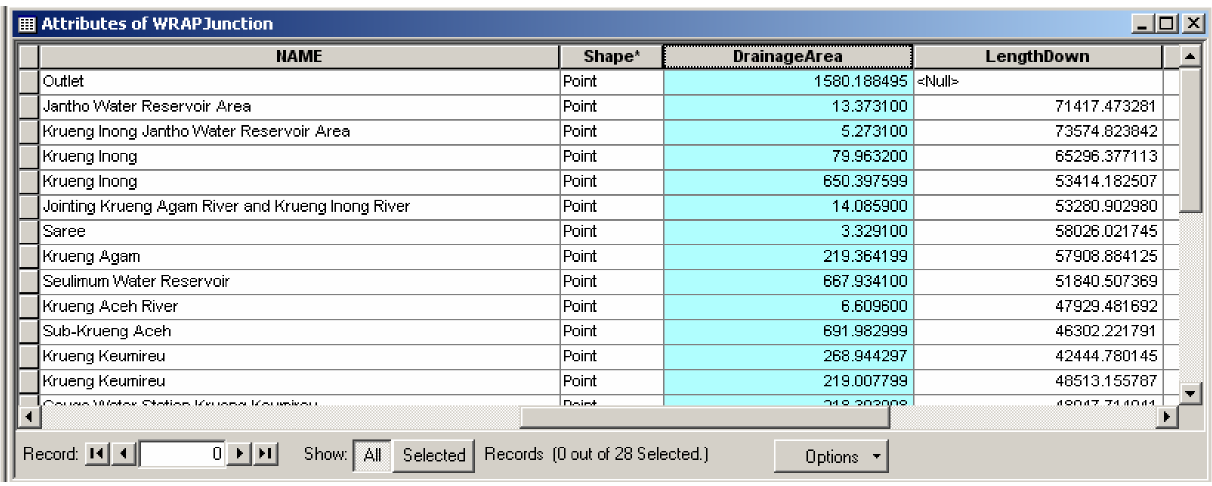
- In the WRAPHydro toolset, select **Advanced Tools / Accumulate CN, Precip and Area**.



A message will appear listing which parameters were successfully calculated when the tool finishes.



The drain area values were added downstream and were stored in the DrainageArea field in the WRAPJunction attribute table. The curve number and precipitation values were populated in the AvgCN and AvgPR fields by taking a weighted average of the respective values over each watershed (if this data is available for processing).



Attributes of WRAPJunction

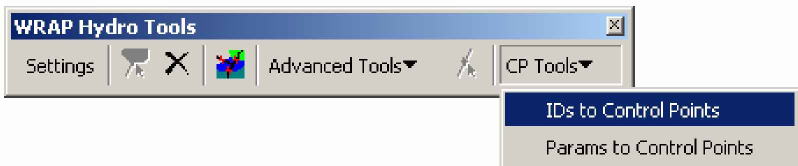
NAME	Shape*	DrainageArea	LengthDown
Outlet	Point	1580.188495	<Null>
Jantho Water Reservoir Area	Point	13.373100	71417.473281
Krueng Inong Jantho Water Reservoir Area	Point	5.273100	73574.823842
Krueng Inong	Point	79.963200	65296.377113
Krueng Inong	Point	650.397599	53414.182507
Jointing Krueng Agam River and Krueng Inong River	Point	14.085900	53280.902980
Saree	Point	3.329100	58026.021745
Krueng Agam	Point	219.364199	57908.884125
Seulimum Water Reservoir	Point	667.934100	51840.507369
Krueng Aceh River	Point	6.609600	47929.481692
Sub-Krueng Aceh	Point	691.982999	46302.221791
Krueng Keumireu	Point	268.944297	42444.780145
Krueng Keumireu	Point	219.007799	48513.155787

Record: 0 Show: All Selected Records (0 out of 28 Selected.) Options

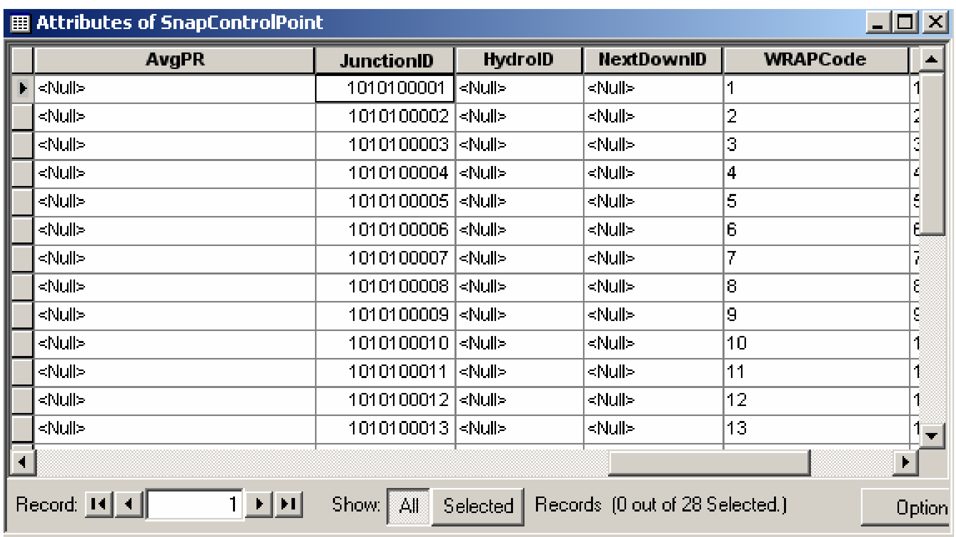
5.4.13 Assign JunctionID to SnapControlPoint.

Objective: The last step in parameter development is to copy the attributes from WRAPJunction to all the points including the coincident ones in the ControlPoint feature class

- Go to **WRAPHydro Tools** / **Settings**.
- Click the **Layers** tab and make sure that **SnapControlPoint** appears as the *Control Point* layer.
- Click the **Fields** tab and make sure that all of the fields for **WRAPJunction** and **Control Point** are filled in. Click **OK**.
- Go to **WRAPHydro Tools** / **CP Tools / IDs to Control Points**.



Each **SnapControlPoint** now is attributed with the **HydroID** of the **WRAPJunction** that lies directly underneath it (**NOT** downstream, but underneath the same point).


Attributes of SnapControlPoint

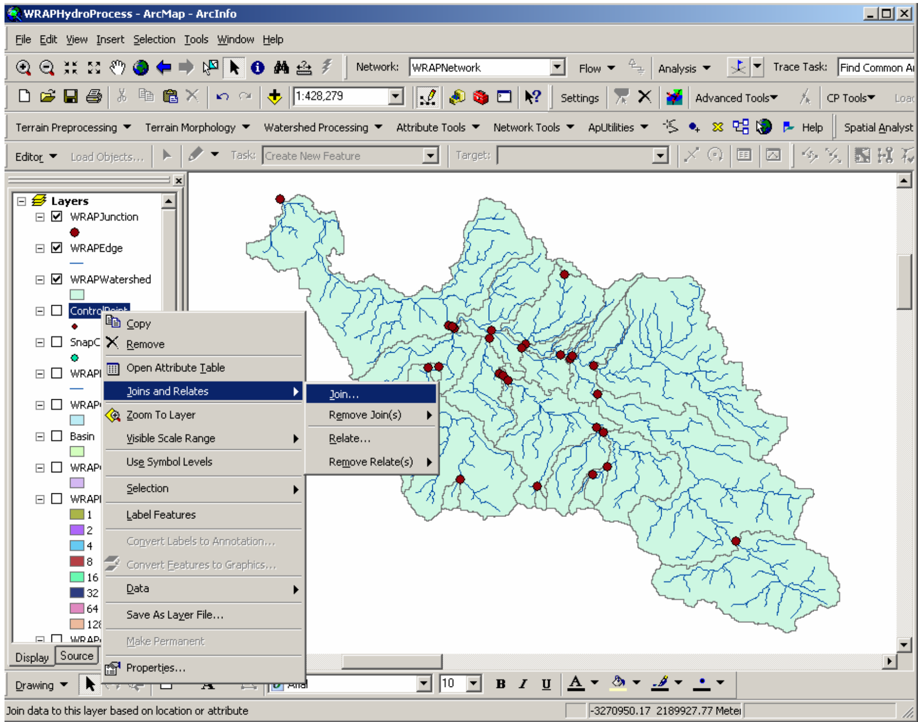
AvgPR	JunctionID	HydroID	NextDownID	WRAPCode
<Null>	1010100001	<Null>	<Null>	1
<Null>	1010100002	<Null>	<Null>	2
<Null>	1010100003	<Null>	<Null>	3
<Null>	1010100004	<Null>	<Null>	4
<Null>	1010100005	<Null>	<Null>	5
<Null>	1010100006	<Null>	<Null>	6
<Null>	1010100007	<Null>	<Null>	7
<Null>	1010100008	<Null>	<Null>	8
<Null>	1010100009	<Null>	<Null>	9
<Null>	1010100010	<Null>	<Null>	10
<Null>	1010100011	<Null>	<Null>	11
<Null>	1010100012	<Null>	<Null>	12
<Null>	1010100013	<Null>	<Null>	13

Record: 1 Show: All Selected Records (0 out of 28 Selected.) Option

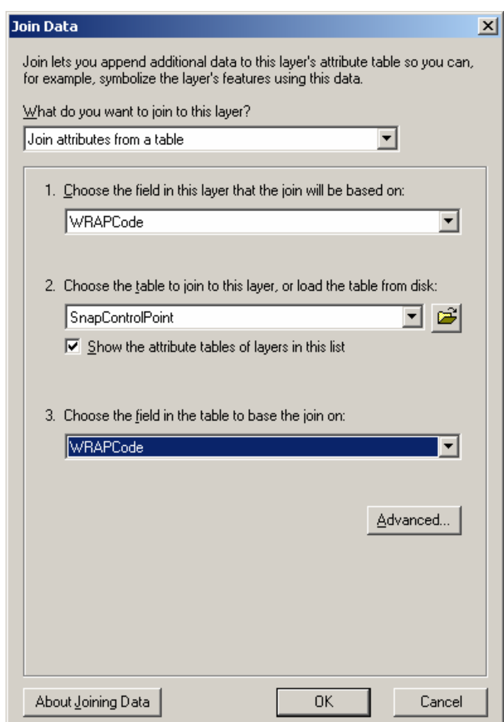
Ultimately, the features in the ControlPoint need to be associated with WRAPJunctions. The SnapControlPoint from the previous step is used because it is easier to locate the correct WRAPJunction from features that are spatially coincident with them. Next, we assign JunctionID values to the corresponding ControlPoints, which are not necessarily spatially coincident with WRAPJunctions.

Each SnapControlPoint and ControlPoint is attributed with a value called WRAPCode. This value is the same for corresponding features between the two feature classes.

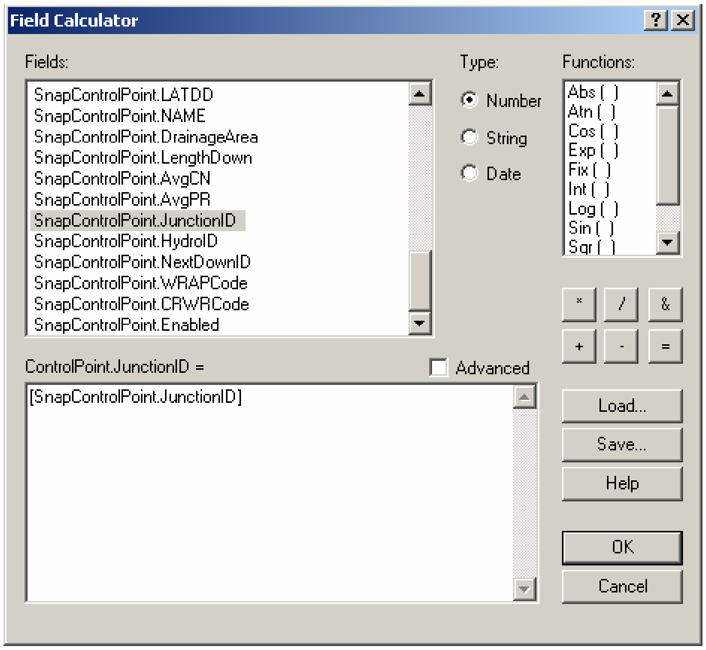
- Right click on the **ControlPoint** feature layer and create a new join with the **SnapControlPoint** layer.



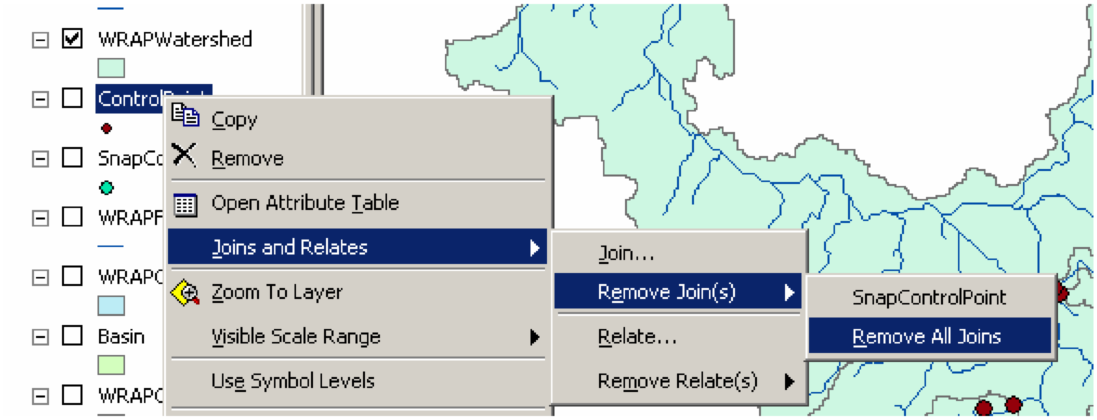
- Base the join on the **WRAPCode** layer and choose the **SnapControlPoint** table to join to the layer. Use **WRAPCode** as the field in the table to base the join on. Click **OK**.



- Once the join has been created, open the **ControlPoint** attribute table.
- Copy the **JunctionID** values from the **SnapControlPoint** feature class to the **ControlPoint** feature class using the field calculator. Click **OK** and close the attribute table.



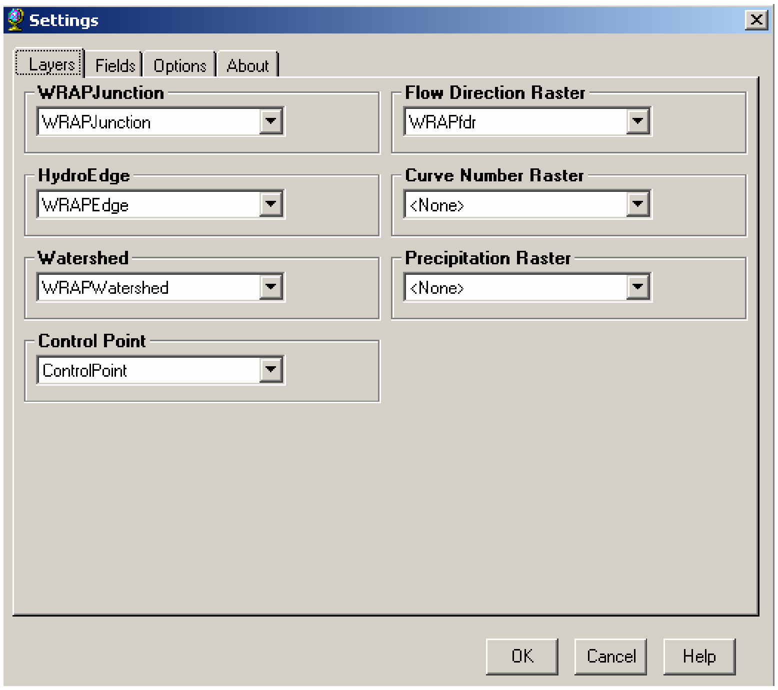
- Right click on the **ControlPoint** layer / **Joins and Relates** / **Remove Join(s)** / **Remove All Joins** to remove joins.



5.4.14 Copy parameters from WRAPJunction to ControlPoint.

There now exists one too many relationships between WRAPJunction and ControlPoint. The "Params to Control Points" tool is used to copy the attributes to ControlPoint. For each match of HydroID in WRAPJunction with JunctionID in ControlPoint, the respective attributes for Drain_Area, AvgCN and AvgPR values are copied to ControlPoint.

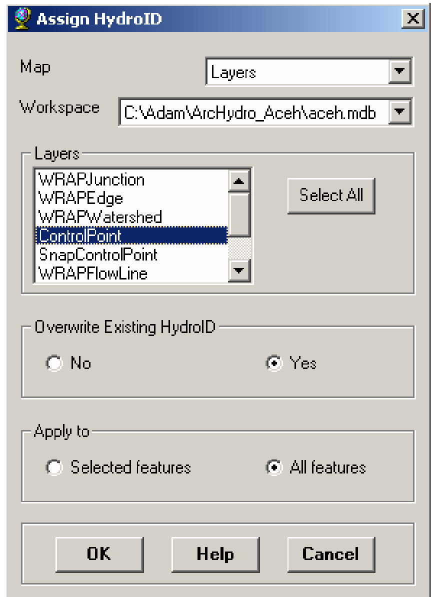
- Go to **WRAPHydro Tools** / **Settings**.
- Click the **Layers** tab and make sure that **ControlPoint** is now the *Control Point* layer (not **SnapControlPoint**).
- Click the **Fields** tab and make sure that all of the fields for **WRAPJunction** and **Control Point** are filled in. Click **OK**.



One of the parameters required by WRAP is the NextDownID for Control Points. Before the WRAPHydro tools can calculate this value, we must assign HydroIDs to ControlPoints in case they do not exist yet.

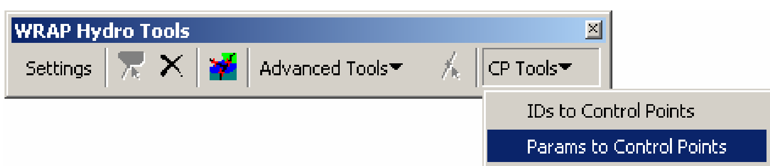
- Go to the ArcHydro tools and click on **Attribute Tools** / **Assign HydroID**.

- Select the **ControlPoint** feature class and click **Yes** to overwrite existing HydroIDs. Click **OK**.

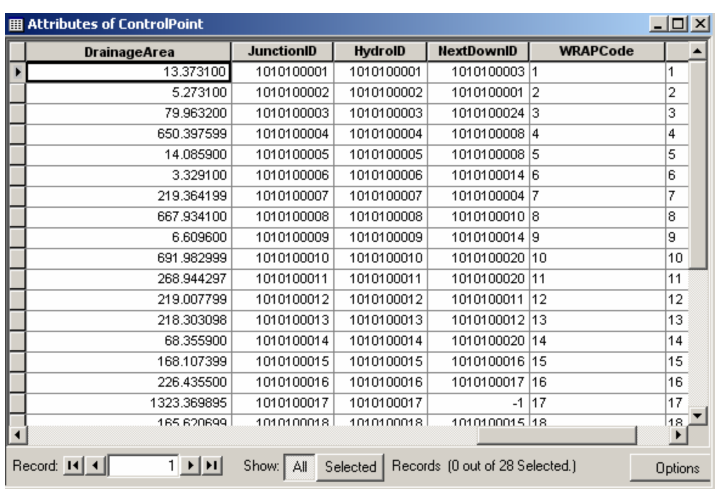


Note that own ID can be used, instead of HydroID, as the ControlPoint identifier. To do so, simply change the HydroID field (and perhaps the NextDownID field) for the Control Point layer in the Settings form of the WRAPHydro tools.

- Go to the WRAPHydro Tools and click on **CP Tools** / **Params to Control Points**.



Finally the Control Point feature class parameters have been populated!!!


Attributes of ControlPoint

DrainageArea	JunctionID	HydroID	NextDownID	WRAPCode	
13.373100	1010100001	1010100001	1010100003	1	1
5.273100	1010100002	1010100002	1010100001	2	2
79.963200	1010100003	1010100003	1010100024	3	3
650.397599	1010100004	1010100004	1010100008	4	4
14.085900	1010100005	1010100005	1010100008	5	5
3.329100	1010100006	1010100006	1010100014	6	6
219.364199	1010100007	1010100007	1010100004	7	7
667.934100	1010100008	1010100008	1010100010	8	8
6.609600	1010100009	1010100009	1010100014	9	9
691.982999	1010100010	1010100010	1010100020	10	10
268.944297	1010100011	1010100011	1010100020	11	11
219.007799	1010100012	1010100012	1010100011	12	12
218.303098	1010100013	1010100013	1010100012	13	13
68.355900	1010100014	1010100014	1010100020	14	14
168.107399	1010100015	1010100015	1010100016	15	15
226.435500	1010100016	1010100016	1010100017	16	16
1323.369895	1010100017	1010100017	-1	17	17
165.620699	1010100018	1010100018	1010100015	18	18

Record: 1 Show: All Selected Records (0 out of 28 Selected.) Options

References

Asamenaw, S.A. and D.C. McKinney, *ArcHydro Data Model for Ethiopian Watersheds*, The University of Texas at Austin, Center for Research in Water Resources Online Report No. 2005-06, 2005

Csillag, F., 1996, *Variation on hierarchies: toward linking and integrating structures*, in Goodchild, M.F. et al (Eds.), GIS and Environmental Modeling: Progress and Research Issues, GIS World Publication, Fort Collins, CO, pp. 433-437

Goodchild, M.F., 1993, *Data models and data quality: problems and prospects*, in Goodchild, M. F., Parks, B.O., Steyaert, L.T., (Eds.), Environmental Modeling with GIS, Oxford University Press, New York, pp 8-15

Gopalan, H. and D.R. Maidment, *WRAPHydro Data Model: Finding Input Parameters for the Water Rights Analysis Package*, The University of Texas at Austin, Center for Research in Water Resources Online Report No. 2003-03, 2003 (http://www.crwr.utexas.edu/reports/2003/rpt03-3.shtml)

Maidment, D.R., 2002. ArcHydro: GIS for Water Resources, ESRI Press, Redlands

Patino, C., D. C. McKinney, and D. R. Maidment, *Development of a Hydrologic Geodatabase for the Rio Grande/Bravo Basin*, AWRA Spring Specialty Conference: Geographic Information Systems (GIS) and Water Resources III, Nashville, TN, May 17-19, 2004

Patiño-Gomez, C. and D.C. McKinney, *GIS for Large-Scale Watershed Observational Data Model*, The University of Texas at Austin, Center for Research in Water Resources Online Report No. 2005-05, 2005 (http://www.crwr.utexas.edu/reports/2005/rpt05-5.shtml)

Wurbs, R.A., and Dunn, D.D., *Water Rights Analysis Package (WRAP) Model Description and Users Manual*, Texas A&M University, College Station, October, 1996